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FUTURE UNDERWATER ACTIVITIES AND THEIR IMPLICATIONS FOR THE COA--ETC(U)

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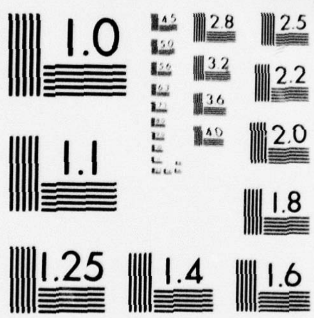
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Report No. USCG-D-65-78 - VOL-3

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FUTURE UNDERWATER ACTIVITIES AND THEIR IMPLICATIONS FOR THE COAST GUARD CIRCA 1978-2000.

VOLUME III

10

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16. Abstract

The objectives of this study is to develop forecasts of underwater activities circa 1978-2000 and to assess the implications of these forecasts for the U.S. Coast Guard.

A macro environmental framework, a marine environmental framework, and an underwater activities systems model were structured to form a baseline for a forecast of underwater activities. Data with which to load the models and frameworks was developed through literature reviews, interviews, and written correspondence. The data was organized for each of the underwater activities under the following headings: Operational Systems, Environmental Requirements, Locations, U.S. National Interests, Implications, and Forecasts. Each activity development was then individually analyzed for future evolution, driving forces, barriers, and obviating factors. Each of the fifteen underwater activity categories within the model was translated into "Tailored Vignettes" for the Coast Guard. A final integrative inventory of forecasted operational systems was developed.

Implications of the underwater activities forecasts were provided and analyzed for the current Coast Guard program structure. Conclusions and recommendations were presented as reasonable and important steps to be taken in order to prepare for the anticipated developments and implications.

This is a three volume report. Volume I is the Executive Summary, Volume II is the Final Report and Analysis of Coast Guard Implications, and Volume III is the Detailed Forecasts of Underwater Activity.

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METRIC CONVERSION FACTORS

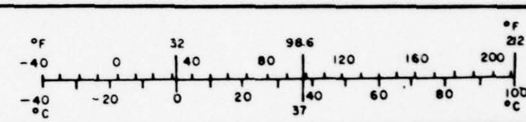
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



METRIC CONVERSION FACTORS

PREFACE

This is Volume Three of a three volume report dealing with forecasted underwater activities circa 1978-2000 and their implications for the U.S. Coast Guard.

The three volumes comprising the total report are:

Volume 1: Executive Summary: a summation of the other two volumes of the report developed with the objective of providing a complete overview of the project.

Volume 2: Basic Report and Analysis of Coast Guard Implications of Future Underwater Activities: a summary of the research process and the analysis of the Coast Guard implications derived from the forecasts presented in detail in Volume 3.

Volume 3: Detailed Forecasts of Underwater Activities: the detailed forecasts for overall underwater activities.

The forecasts are not meant to be exhaustive scenarios containing all aspects of future underwater activities, or all possible "alternative futures." Rather, they are tailored to concentrate upon illuminating those aspects of future underwater activities that will help to define the relationships to Coast Guard missions and operational responsibilities. These are termed "Tailored Vignettes." The concept of "tailored" means that a specialized interpretative dimension to the forecasts is being derived. The concept of "vignette" means that a middle ground is being adopted between comprehensive scenarios of all future possibilities and the event-oriented forecast. The former suffers from a level of generality which makes specific operational implications difficult to define. The latter, the event-oriented forecast, suffers from a specificity which inhibits the needed integrative insights. The "vignette" concept provides a useful "middle ground."

We have presented our conclusions in the form of forecasts and probability estimates within three basic time phases--1981-85, 1986-92, and 1993-2000.

The reader should approach these and all long range forecasts with an acute awareness that:

- The most difficult problem in comprehending probable future developments is overcoming the tendency to perceive the future only as a mirror image of our current operational day-to-day experiences.

- There is no single "right" or "wrong" view, for there cannot be that desired degree of scientific prediction. One is dealing with an art form replete with qualitative as well as quantitative information and judgments, interlaced with societal values, and the complex interactions of scientific, technological, economic, political, and social developments.

- We have sought to provide the reader with sufficient rationale and analysis to understand how we have derived our views, and if he so wishes, to have a baseline from which to develop alternate views if he deems our views to be invalid.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

As will be seen in later chapters, we envision significant changes in underwater activities. Virtually all of these developments entail substantial implications for the Coast Guard. The following brief summation will suggest some of the highlights which are developed in more detail throughout the following chapters:

- Some major changes will occur in traditional concepts of marine military operations. The underwater arena will become proportionately more important. There will be substantial growth in the type and scale of military activities in the underwater environment.
- Non-military operations concerned with the protection of property and life will also expand dramatically as a result of the: growing range of underwater activities; growth in antisocial technologies through which to disrupt marine activities; growing probabilities that such technologies can and will be used in extra-legal ways; growth in capabilities to predict natural catastrophies; and growing potential for accidents.
- The marine environment will become much more involved with economic activities in all significant categories: energy, mining, marine agriculture, transportation, management of the injection of foreign elements, and recreation.
- While we do not believe extensive underwater habitation will occur as a permanent alternative to land based living, we do foresee some temporary human habitats to serve functional or recreational purposes.
- Requirements for and technologies to achieve surveillance and monitoring will be a dynamic area.
    - Scientific research will continue in a growing number of areas.
    - Regulation, standard setting, enforcement and inspection requirements will grow substantially, and they will cover a number of new fields.

Our concept of presenting these forecasts in the form of "tailored vignettes" is discussed in the Preface.

These vignettes were developed from an integrative analysis which blended together three frameworks:

- The Macro Environmental Framework: A structure which contains the trends and developments which affect all institutions within our society and are in essence a generalized context common to all.

- The Marine Environment Framework: A structure which contains the trends and anticipated developments within the overall marine environment.
- The Underwater Activities System Model: A structure which contains a more detailed analysis of trends and expected developments within the underwater environment; i.e., the specific domain with which we are concerned. This model contains:
  - 13 basic categories or classes of activities
  - 106 more specific activity areas which represent the level of the structure needed to forecast activities and access the related Coast Guard implications
  - basic techological/operational systems which will be employed within the underwater environment in the conduct of the above 106 types of activities.

Tailored vignettes have been developed for each of the thirteen basic categories and are discussed as individual chapters within this report. However, these vignettes are highly interrelated and share in common many of the operational systems that will be found in use.

Chapter 15 presents an integrative summation of these operational systems which we expect the Coast Guard to encounter in the future underwater environment. These operational systems provide an important mechanism through which to develop the Coast Guard implications discussed in Volume II.

Within each activity category and its related chapter, the tailored forecasts are presented in the following format:

- Definition: specific coverage of the activity
- Background: giving a few salient points which place the activity into historic perspective and give an overview or backdrop for the major future developments
- Functional System: outlining the components of the functional system which is required to to conduct the activity
- Geophysical Perspectives: outlining the required geophysical attributes and sketching where these conditions are generally met within the territorial waters of the U.S.
- Tailored Forecasts: outlining the rationale and substance of the forecasts which will describe the conditions which will be encountered if one walks through the anticipated future

The tailored forecasts contain the following subsections:

- Key Basic Concepts: brief outlines of the key ideas and/or concepts for possible future developments. These are discussed in relation to each component of the operational system discussed above.
- Key Driving Forces: brief definition of the forces which will have the most impact upon moving the activity foreward.
- Key Barriers: brief description of developments which could simply eliminate the driving forces and the factors causing the activity to emerge or continue to develop.
- Tailored Vignettes: our forecasts of future underwater activity discussed in terms of key substantive characteristics that will likely be found in existence These are assigned probability estimates of high, good, low and minimal within three time frames: 1981-85, 1986-92, 1993-2000.

The above information is summarized within each activity forecast in several standardized figures:

- One which sketches the components of the operational system
- One or more which list in columnar form the following: Basic Key concepts, Key Driving Forces, Key Barriers and Obviating Factors.
- One which summarizes in outline form the substantive forecasts with probability estimates for each of the three basic time periods

In developing the tailored forecasts the rationale and analysis proceeded in the following sequence:

1. A judgment was made relative to each of the obviating factors. If they are to become operationally significant then the forecast would be for a reversal of the driving forces and perhaps no presence of the activity within the marine environment, at least within the time frame for this project.
2. Analysis of the key barriers. The question here becomes whether they will be sufficient to block emergence of the activity or to affect the manner in which it emerges. If they are expected to block it entirely they become the equivalent of obviating factors. If, however, they are to interact in affecting how the activities emerge and are conducted they are integrated with the analysis of the driving force to derive a judgment of how the future developments will likely unfold. In essence, one is estimating how the problems raised by the barriers will be resolved.

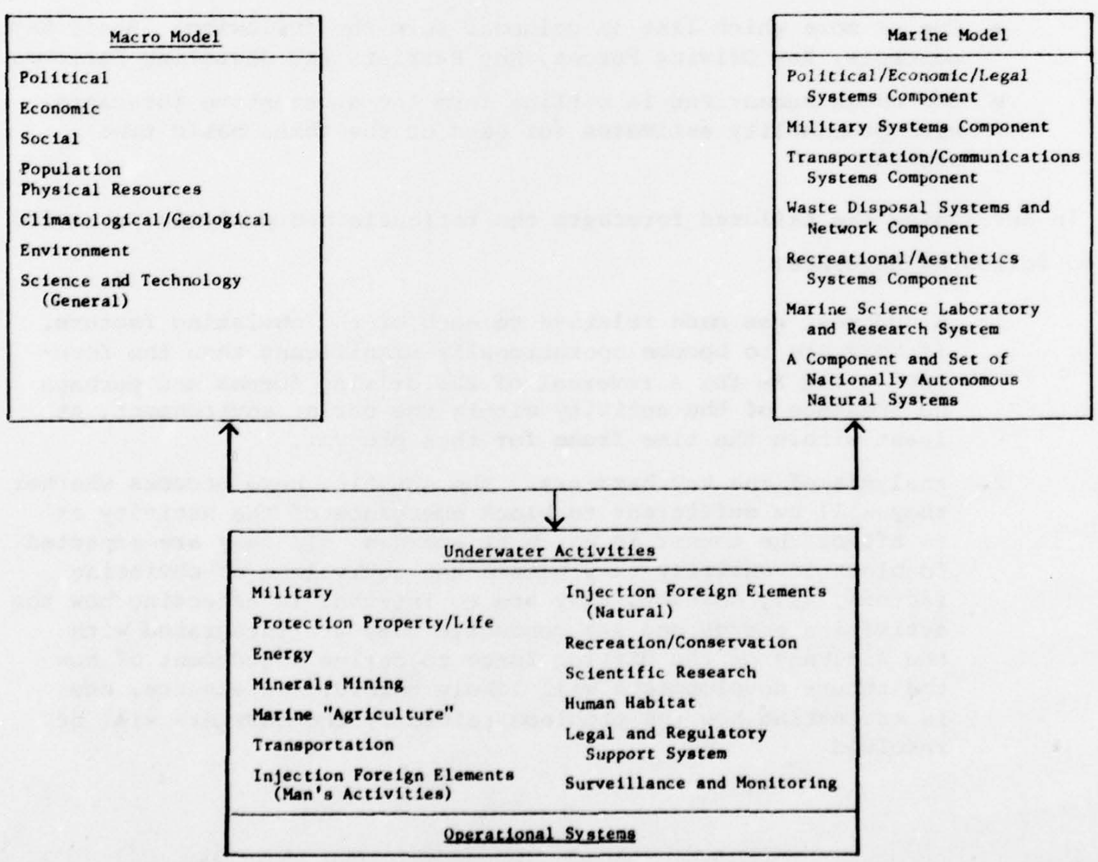
3. Analysis of the ultimate direction and substantive composition of the driving forces, and how they are ultimately reconciled to the issues raised by the key barriers. This analysis integrates the alternative technological concepts of what might occur with the social, political and economic factors to derive our judgment of what is most likely to occur. This analysis also is used to develop our independent estimates of the probabilities.

Once each activity has been individually forecasted, all activity forecasts were interrelated in a cross impact matrix analysis which may have caused a modification to the previous individually developed forecast. These modifications were made and the final tailored vignettes derived.

THE UNDERWATER ACTIVITIES SYSTEM MODEL

As noted above, two conceptual/environmental frameworks have influenced both the structure and the forecasts of the Underwater Activities System. An outline of the structure of these two frameworks, plus the thirteen major categories of the Underwater Activities System Model are shown in Figure 1-1.

FIGURE 1-1: OVERVIEW OF CONCEPTUAL FRAMEWORKS



STRUCTURE OF THE UNDERWATER ACTIVITIES SYSTEM MODEL

As is shown in Figure 1-2, the Underwater Activities System Model contains thirteen basic activity categories. For purposes of this analysis, these categories can be viewed as specific functional purposes/missions related to operations within the underwater environment.

Each of these major categories contains a number of more specific activities. There are 106 such specific activities within the model.

Finally, each of the activities has one or more basic operational systems associated with it. The integrated inventory of these operational systems is developed in Chapter 15. A summary of that inventory is shown in Figure 1-2 along with the major activity categories and the specific activities.

Definitions of each activity are developed in the relevant chapters.

It must be remembered that the available technologies and resources are themselves largely determined by how the Coast Guard acts and plans now. Likewise, the roles, missions and responsibilities, which will be ultimately assigned to the Coast Guard, are heavily affected by the organizational effectiveness, credibility and foresight. By virtue of these realities, the organizational structures of the federal government may be further influenced by both current and future activities of the Coast Guard as well as the other federal agencies involved within the marine environment.

For these reasons, the analysis and estimation of Coast Guard implications begin with a brief tailored forecast of the future roles of government vis-a-vis the marine environment, followed by the organizational structures of the federal government, and of the probable roles and responsibilities which will be assigned to the Coast Guard. From this perspective, the analysis translates the forecasted underwater activities into sets of requirements, which will be levied upon the Coast Guard. These requirements are discussed in terms of implications at two levels:

- General implications for the Coast Guard as a whole
- Specific implications associated with the functions reflected in the current program structure

Those overall requirements that cannot be fit into the current program structure are discussed separately as apparent or potential "organizational/structural gaps."

It should be emphasized that the implications at both levels represent our independent view of the essential characteristics of the requirements, which will need to be met.

They do not represent any assessment or evaluation of whether these characteristics are already present, under development, or just planned. That evaluation should be the next step, but it is beyond the scope of this assignment.

In the next chapter, the integrated outline of the forecasted underwater activities and operational systems is presented. The Underwater Activities System Model upon which those forecasts were derived is presented below.

FIGURE 1-2: THE UNDERWATER ACTIVITIES SYSTEM MODEL

13 BASIC ACTIVITY CATEGORIES	106 ACTIVITIES	OPERATIONAL SYSTEMS
Military	Submarines as Weapons Mines Individuals/Teams Underwater Installations Underwater Logistical Support Surface Weapons Systems Interface Land Based Weapons Systems Interface Surveillance/Monitoring Search and Rescue R&D Marine Mammals Chemical/Biological Warfare	**General Systems and Operations** **1) Submersibles** **a. Design Characteristics** • **Manned and unmanned** • **Tethered, untethered, towed** • **Bottom crawlers** • **Remotely controlled** • **Lock in/lock out system** • **Depth range** • **Size variation** **2) Habitats**
Protection of Property/Life	"Aggression" from Nonmilitary Forces Against Nonmilitary Targets Natural Disasters Major Accidents Involving Property and Human Life Salvage	**a. Design Characteristics** • **Temporary underwater** • **Temporary sea surface** • **Permanent underwater** • **Permanent sea surface** • **Lock in/lock out system** • **Ocean bottom** • **Size variations**
Energy	Offshore Oil and Natural Gas Offshore Coal Production Offshore Uranium Production Floating Solar Heat Collectors Floating Windmills Ocean Thermal Energy Conversion (OTEC) (Continued)	**3) Working Platforms/Rigs** **a. Design Characteristics** • **Stilt supported** • **Submerged drilling bar** • **Jack up barges** • **Semisubmersibles** • **Floating platforms** • **Ocean bottom** (Continued)

FIGURE 1-2: THE UNDERWATER ACTIVITIES SYSTEM MODEL (Continued)

13 BASIC ACTIVITY CATEGORIES	106 ACTIVITIES	OPERATIONAL SYSTEMS
Energy (Continued)	Tidal Power Ocean Currents Wave Energy Deep Sea Pressure Power Ocean Hydropower Water Salination Power Underwater Geothermal Energy Kelp and Other Aquatic Vegetation Nuclear Power Plants Natural Gas Process Plants Other Power Plants, Refineries, or Conversion Centers Industrial Process Plants and Other "Consumers" Located for Direct Consumption of Ocean Generated Energy	4) Dredges a. Design Characteristics • Semisubmersible • Submersible • Ocean bottom • Surface b. Functional Type • Cutter suction • Suction hopper • Continuous bucket line • Vacuum cleaner 5. Harvesting Systems a. Nets • Purse seines • Drift nets • Bottom dwelling • Long lines • Trawling b. Lines c. Hooks d. Traps e. Electronic stunners 6. Surface Vessels a. Size variations b. Conventional hull design c. Platoon structure
Minerals Mining	Oil and Natural Gas (see Energy) Coal (see Energy) Sulfur Hard Rock Minerals Fresh Water Aquifiers Sand and Gravel Limestone and Shell Placers Manganese Nodules Red Clay/Ooze Chemical Extraction (Continued)	(Continued)

FIGURE 1-2: THE UNDERWATER ACTIVITIES SYSTEM MODEL (Continued)

13 BASIC ACTIVITY CATEGORIES	106 ACTIVITIES	OPERATIONAL SYSTEMS
Minerals Mining (Continued)	Desalination	d. Hydrofoil
	Icebergs	e. Open stern trawlers
		7. Divers
Marine "Agriculture"	Fish and Shellfish	a. Pressurized suits
	Marine Organisms	b. Tank equipped
	Marine Plants	c. Other
		• Dry suits
Transportation	Inland Port Operations	• Wet suits
	Coastal Port Operations	• Scuba
	Offshore Port Operations	8. Instrumentation Systems
	Underwater Vessels	a. Navigational aids
	Surface Vessels	• Transponders
	Diving Without Vessel	• Transceivers
	Cables	• Cameras
	Pipelines	• Strobes
	Tunnels, Bridges, Causeways	• Viewing ports
Injection Foreign Elements: Man's Activity	DELIBERATE INJECTION	b. Communication and surveillance mechanisms
	Municipal Residuals	• Visual
	Industrial Residuals	Direct
	Dredge Residuals	Photography
	Marine Operations	• Electromagnetic
	Radioactive Materials	Radar
	ACCIDENTAL INJECTION	Infrared
	Municipal	Laser
	Industrial	Other
	Marine Operations	(Continued)
	Radioactive Materials (Continued)	

FIGURE 1-2: THE UNDERWATER ACTIVITIES SYSTEM MODEL (Continued)

13 BASIC ACTIVITY CATEGORIES	106 ACTIVITIES	OPERATIONAL SYSTEMS
Injection Foreign Elements: Man's Activity (Continued)	SUBLIMINAL INJECTION Runoff Atmospheric Settling MANAGED INJECTION Nutrients Ecostabilizers and Restorers Naturally "Disposables" Artificial Reefs and Barriers	c. Communication and surveillance components ● Hydrophones ● Cameras ● Underwater transmit 9. Underwater Hardware a. Manipulators b. Cables ● Support ● Electric c. Pipelines d. Buoys e. Mines
Injection Foreign Elements: Natural	Atmospheric Settlement Continental Runoff Subterranian Upheaval	
Recreation/Conservation	Unique Points of Interest, e.g., Underwater Caves, Coral Fields, Historic Shipwreck Sites, etc. Critical Habitats for Endangered Living Resources Recreational, Aesthetically Appealing Sites Other Designated Sites	
Scientific Research	Resources Inventory Meteorlogical Relationships Physical Forces (Tides, Currents, etc.) Physical Chemistry Compositions and Dynamics Geological/Geophysical Phenomena and Dynamics Biological/Biochemical Compositions and Dynamics	

(Continued)

FIGURE 1-2: THE UNDERWATER ACTIVITIES SYSTEM MODEL (Continued)

13 BASIC ACTIVITY CATEGORIES	106 ACTIVITIES	OPERATIONAL SYSTEMS
Scientific Research (Continued)	Marine Life Systems of "Higher Organisms" Marine Plant Life Systems Human Organisms in Undersea Environment Engineering Technologies/Systems for Underwater Operations Resource Development and Management International Geopolitical Issues and Resolutions Other Marine Management Issues	
Human Habitat	Temporary "Mobile" or "Transportable" Units Permanent Units Rotational Occupancy Total Living Habitation Direct Worker Quarters Industrial Complex Industrial and/or Commercial Residential Complex Residential Complex	
Legal and Regulatory Activities and Support Systems	Not applicable	
Surveillance and Monitoring	Threat Identification Intelligence Navigation Law Enforcement Search/Rescue/Salvage	

CHAPTER 2: MILITARY ACTIVITIES

DEFINITION

This category includes all overt and covert activities related to the underwater environment conducted by formally established military organizations which are a part of a sovereign government, or by related organizations operating under the command and control of such military organizations. By and large, during peace time or a state of undeclared war, within the U.S. government, military activities are limited to those of the Department of Defense, its coordinated efforts, and its contractual supporters.

Military organizations operate as a component of governments in carrying out various national objectives. Military activities are conducted in both the marine and nonmarine environments. Within the marine environment they are conducted above, on, and beneath the surface. Our concern here is limited to the marine-related military activities that have a direct interrelationship with the underwater environment. Such activities can be classified into one or more of the following sets:

- Submarines as weapons
- Mines
- Individuals/teams
- Underwater installations
- Underwater logistical support
- Surface weapons systems interface
- Air-based weapons systems interface
- Land-based weapons systems interface
- Surveillance/monitoring
- Research and development
- Marine mammals

BACKGROUND

The capability to traverse the seas and to operate militarily within them has been an important component of military objectives for centuries. But until the advent of the first submarine during the Civil War these marine activities were almost exclusively restricted to surface vessels. The 20th century introduction of aircraft, missiles, and satellites along with dramatic

innovations in underwater technology has lead to a rapid development of military activities conducted above, on, and beneath the ocean surface.

Our forecasts related to underwater military activities are developed against the following backdrop of macro/marine environmental forecasts:

- Overall political, economic, and technological developments will continue to emerge wherein there are more nations who are significant in world affairs and who increasingly are equipped with military organizations operating at all points of the spectrum from conventional warfare (as currently defined) to the nonconventional capabilities of nuclear, biological, chemical, and other forms of modern weaponry. We refer to this overall spectrum of potential destructive capabilities as antisocial technology.

- The historic "monopoly" by military organizations to develop and operate antisocial technologies will erode and the capability will be transferred to divergent organizations.

- There will continue to be a major need for military capabilities as instruments of national policy and power.

- The U.S. will continue to seek to retain its role as a major world power, and in so doing will find that it must maintain military parity along with many other forms of competitive parity including the capability to operate at any and all points on the antisocial technology spectrum.

- Technological developments are bringing about a climate within which the fundamental doctrines of naval warfare will have to be changed. This shift primarily will be one which makes military activities within the underwater environment much more important in terms of absolute quantity and proportionately more significant within overall military capabilities.

- The arms race will continue to move into the next generation development which will include both proliferation of nuclear power and the development of other antisocial technologies of a nonconventional type. The national capability to destroy life and property will increase significantly, and this capability will be more widely dispersed in the world.

- The evolution of the marine economy will make new demands on marine military activities. Particular areas of concern include the defense of offshore resources, rights of passage, and protection of territorial waters.

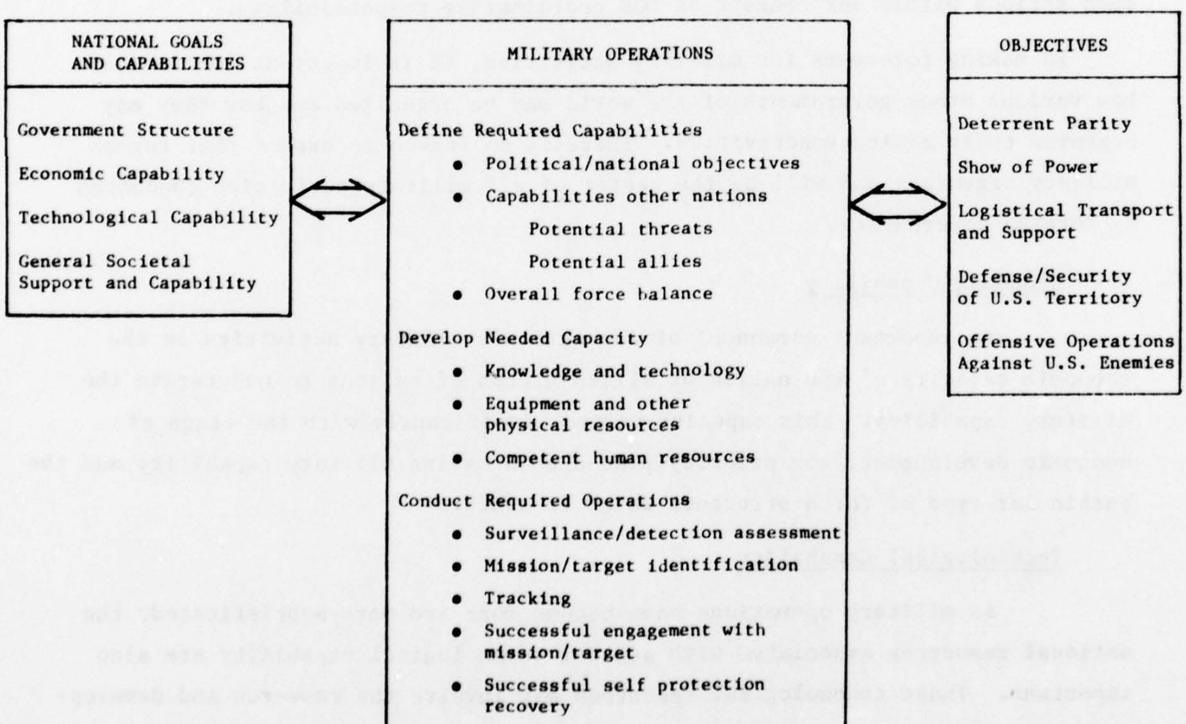
Some of the details related to these developments are discussed in the remainder of this chapter and in the following chapters.

FUNCTIONAL SYSTEM

There are three areas within the functional system (Figure 2-2):

- Objectives to be achieved through military capabilities
- National goals and capabilities
- Military operations which unite the national goals and capabilities with the objectives

FIGURE 2-2: OPERATIONAL SYSTEM FOR MILITARY ACTIVITIES



NATIONAL GOALS AND CAPABILITIES

Governmental Structure

In the definitional section, military activities were limited to those operations conducted under the authority of a sovereign government. Within the U.S., these operations are exclusively under the control of the federal government and they are conducted primarily by the Department of Defense. It should be noted, however, that all military activities need not be, nor are they centered, within the Department of Defense. Many such activities may be conducted by other agencies, but are normally within the coordinative relationship with the DOD. State governors can summon the National Guard, which is a part of the U.S. military establishment for purposes of emergency action within the boundaries of individual states. However, we are including such actions within our concept of DOD coordinative responsibility.

In making forecasts for military activities, it is important to consider how various other governments of the world may be organized and how they may organize their military activities. There is no reason to expect that formal military organizations will be the center of all military activities conducted by foreign governments.

Economic Capability

An important component of any nation's military activities is the economic capacity of the nation or allied groups of nations to underwrite the military capability. This capacity varies significantly with the stage of economic development, the priority placed upon having military capability and the particular type of force structure which is sought.

Technological Capability

As military operations have become more and more sophisticated, the national resources associated with general technological capability are also important. These technological resources may involve the research and developmental leadership role or they may entail only the capability to import technological developments emerging elsewhere.

General Societal Support and Capability

Important to any significant military capability is the general societal support which is essential to the effective mobilization of the national

will, power and capacity. This factor is important in all governmental forms but is especially important within world democracies.

OBJECTIVES OF MILITARY ACTIVITIES

The objectives that military activities seek to achieve are many fold, but can generally be grouped into the following basic classifications:

- Maintenance of deterrent parity: the development and maintenance of a military capability for retaliation which is sufficiently credible to deter anyone from practicing military aggression against the U.S. or its allies.
- Show of power: the occasional employment of physical visiblity of military capabilities to show power as an instrument of diplomatic negotiations, to preclude aggressive acts of other nations, or to support U.S and allied negotiations related to various national objectives.
- Logistical transport and support: activities related to marine military operations which are associated with moving men and materials from one place to another and supporting them while there. These operations apply to the logistic support of air and land forces located overseas.
- Defense/Security of U.S. Territory: the capability to secure all U.S. territories or, as appropriate, the territories of U.S. allies from aggression of all kinds.
- Offensive operations against U.S. Enemies: the capability to use the most immediate and effective military means to destroy a declared enemy's capability to fight or to threaten the security of the U.S. These types of activites are normally confined to a state of declared hostility.

MILITARY OPERATIONS

The military operations which connect the above national goals and capabilities, and military objectives entail three basic types of activities:

- Defining required capabilities: which are derived from a combination of political/national objectives; decisions about overall force balance and type of structure among the air, land and sea forces, and the perceived capabilities of other nations who are either potential threats or potential allies.
- Development of needed military capability: a combination of knowledge and technology, equipment and other physical resources, and competent human resources.

- Conduct of required operations: the functional subcomponents are grouped as follows:
    - Surveillance, detection and identification
    - Mission/target identification
    - Tracking
    - Successful engagement with mission/target
    - Successful recovery from engagement with mission/target or from enemies attack

Geophysical Perspectives

Submarines generally operate in deep water beyond the OCS.

The ocean thermal gradient is a key factor in a submarine's ability to remain hidden. Sea water temperature tends to decrease with depth. This temperature gradient tends not be to uniform, but to exhibit an abrupt steep high gradient layer at depths of from less than 100 feet to several hundred feet. This layer refracts active acoustic echo ranging to render submarines below the layer invisible from the surface. Submarine operations tend to favor regions of the world where the layer is reasonably prevalent and close to the surface. These regions tend to be in the tropical or near-tropical waters.

Surface ships have two possible responses to submarines' use of the thermal layer for cover: very high power low frequency sonar, and sonar towed below the layer. Low sonar frequencies are attenuated in sea water less than the higher frequencies. Low frequencies also require large massive sonar transmitters.

Military mining operations tend to be more effective, and the purpose of mining tends to be better served, in shallow water near coastlines. Mining operations are affected by ocean currents, but to date the predictability of these currents has been insufficient to promote use of currents to carry mines to desired locations. Presently, mine technology has not produced mines which can discriminate effectively between friendly or hostile craft; hence, mining operations have been carried out (traditionally) in waters not frequented by friendly or even neutral forces.

Human swimmers or divers operate most effectively near the surface at reasonably short distances to targets. The same is true of trained mammals; however, they can operate at a greater depth. It appears likely that trained mammals will be most effective in physical environments reasonable similar to their native habitats.

Ocean surface installations are likely to appear first in relatively shallow depths, and to find only limited applicability beyond the OCS even in the distant future.

Submarine logistic support forces will not be limited by water depth or distance from bases. Such forces will take advantage of the thermal layer to enhance their concealment through long transits.

Long range surveillance in the marine environment beneath the surface is most effectively accomplished through acoustic means. Acoustic technology is, and will continue to be, beset with serious problems of noise and sound refraction and attenuation. These problems are less intense in deep ocean waters than in the shallower water over the OCS. The difference in transparency between deep and shallow waters will continue to be a factor for acoustic technology.

TAILORED FORECASTS

Key Basic Concepts

The key basic concepts involve a blend of both social and physical technologies and are outlined in Figure 2-3. Since many of the concepts are somewhat overlapping, the following text does not relate in a direct one-to-one manner to each of the entries in the figure. However, sufficient information is discussed to facilitate making the needed relationships.

Governmental Structures

The specific national goals and capabilities related to underwater military activities are defined and made operational through governmental structures.

FIGURE 2-3: TAILORED FORECASTS FOR UNDERWATER ACTIVITIES RELATED TO MILITARY SYSTEMS

OPERATIONAL SYSTEM COMPONENT: NATIONAL GOALS CAPABILITIES

BASIC CONCEPTS	KEY DRIVING FORCES	BARRIERS	OBVIATING FACTORS
<u>Government Structure</u>	US/USSR Power Struggle	Trends Toward UN Settlement of Disputes, Allegiance to UN and its Principles	Hostile Exchange of Megaton Weapons Between U.S. and USSR or PRC
Employment of Military Forces as Instruments of National Policy	The Personal Motivation to Power of World Leaders, and its Related Projection into the Foreign Policy of the State	Growing Awareness of the Consequences of Uncontrolled Military Conflict	U.S./USSR Extensive Conventional Warfare Using Naval Forces in U.S. Coastal Waters
Degree of Reliance on National Sovereignty to Protect National Interests	Emergence of the Third World	Significant Extensive Success of SALT	Drastic Strides Forward in One World Movement, i.e., Disarmament
Degree of Reliance on "Winning" the Arms Race to Insure Adequate Defense Capability	Proliferation of New Sovereign States in the Third World, Especially in Black Africa	Growing Aversion to Settlement of Disputes by Military Force	Drastic Increase in Economic and Military Interdependence Among Nations--Emergence on a Large Scale of the New International Economic Order, for example
<u>Economic Capability</u>	Proliferation of Nuclear Energy Technology to Third World Countries, and its Related Potential for Nuclear Weapon Proliferation	Slowness of Technology Transfer Institutionalizing	Collapse of U.S. and/or Other Leading Economies
Attribution of High Priorization to Military Capability in Allocation of National Economic Resources	The "Great Power Responsibility" Syndrome	Cultural Factors in Emerging Nations Which Inhibit Change	
Perception of Development of Military Capability to be a Stimulus to Economic Development	Worldwide Resource Shortage	Motivation Toward World Peace Keeping by the U.S., and Other Developed Nations, Through Nonmilitary Means	
Use of Potential Adversaries' Military Capability as the Criterion for Assessing Own Adequacy (rather than, for example, Percent of Own GNP)	Discovery of Accessible Resources in the Presently Unclaimed Regions of the Marine Environment	Proselytization of "Pacifism" as a Problem Solving Mechanism	
	Trade Barriers	Nuclear Nonproliferation Agreements	
	Increasing Resource Interdependence and Resource Dependence	Policy Restraints on Military Exports and Technology Transfer	
	Catalytic Effect on Spreading of Military Conflict of the Specific Conflicts in the Middle East, Sub-Sahara, and Southeast Asia		
	Technological Push Toward Development and Use of the Most Advanced Technology Weapons		

(Continued)

FIGURE 2-3: TAILORED FORECASTS FOR UNDERWATER ACTIVITIES RELATED TO MILITARY SYSTEMS (Continued)

OPERATIONAL SYSTEM COMPONENT: NATIONAL GOALS CAPABILITIES

BASIC CONCEPTS	KEY DRIVING FORCES	BARRIERS	OBVIATING FACTORS
<u>Technological Capability</u> High Technology Intensity in National Economy	Shifting Balance Among Nations in Innovative Technological Leadership	Technological* Economic*	Drastic Reduction in Incremental Military Benefits From Technological Advances
High Technology Leadership (as Contrasted With, for example, Imitation of Others' Technology)	Emergence of Economic Systems in the Third World Which are Susceptible to Receipt of Technology Transfer		
<u>General Societal/Support/Capability</u> Reliance on Own Capability for Security vs Reliance Upon Alliances	Propensity Among Nations Towards Ideological Proselytizing	Candor and Openness Among Nations (Fraternity Among Nations)	Drastic Change in U.S. Public Attitude Towards Avoiding use of Military Power
Degree to Which "National Security" is Seen as a Strictly Military Problem	Mutual Distrust Among Nations; Weakness of Alliance Structure		Drastic Reduction in Responsiveness and Preparedness of U.S. to Perceived Highly Threatening Events
Distance, Figurative as Well as Literal, From Own National Boundaries From Which a Threat Would Be Perceived.	Traditional View of the Effectiveness of Military Power? National Paranoia Which Perceives Distant and Unrelated Events as Intended Threats		
Degree to Which the Military Component of National Security Dominates Other Components--Such as "passivity" or Aggression Tolerance Level to "Affront" From Foreign Source	Perception of Own "Interests" as Lying in Far-Distant Lands in Insignificantly Related Issues; Military Alliances Which Foster Dependency of Others Upon U.S.		
		*Technological and Economic Barriers Exist Virtually to All Changes Suggested in This Tabulation.	

(Continued)

FIGURE 2-3: TAILORED FORECASTS FOR UNDERWATER ACTIVITIES RELATED TO MILITARY SYSTEMS (Continued)

OPERATIONAL SYSTEM COMPONENT: MILITARY OPERATIONS

BASIC CONCEPTS	KEY DRIVING FORCES	BARRIERS	OBVIATING FACTORS
<u>Defining Required Capabilities</u> Political/National Objectives Role in World Power Assessment of Others' Interest Economic Interdependency Concepts of Security Assessing Capabilities of Other Nations U.S. and Allies Potential Adversaries Overall Force Balance Relative Allocation of Fixed Military Resources Among Different Uses (e.g., Air, Surface, Subsurface) Assessing Effectiveness in Each Use	Parity as a Measure of Military Adequacy--Strategic, Nuclear, Military, or Some Other Form of Parity Policy to Be Militarily Ready for All Possible Contingencies Belief in the Effectiveness of Archaic Forces to Demonstrate Military Supportive Intent Misleading/Inadequate Intelligence as to Potential Adversaries" Military Capability Perceived Military Weakness of Allies Uncertainty as to the Point of Aggression of a Potential Adversary	Federal Government Budget Constrainers Antimilitary Politics in Executive and Legislative Branches Mistaken Judgments as to Popular Sentiments with Respect to Particular Military Initiatives Which Lead to Uprisings Against These Initiatives Policies That Restrict the Military Budget to a Percent of the GNP or Which Restrict Increases to a Percent of the Previous *Year's Budget*	Success of SALT and Other Disarmament Efforts U.S. Isolationism Coupled With Drastic Reduction, for whatever Reason, of USSR and PRC Military Capability Confidence in Long Lasting Detente and in Settlement of Disputes in N. Korea, Middle East, SEA, and Sub-Sahara Africa International Agreements on Allocation of the Resources and Territories of the Marine Environment Discovery/Development of Vast, Inexhaustible, and Accessible Energy, Food, and Mineral Resources in the Land Environment
<u>Developing and Operating Needed Military Capabilities</u> Surveillance, Detection, and Identification Localization and Tracking Command and Control Transport/Delivery Mechanisms Payloads (Specific Forms of Destructive Technology--See Text) Assessment Self Protection & Recovery Logistics	Perception of Future Trends by Own Forecasting Need for Improvements to Weapons in the Following Respects: Range, Speed, Weight/Size Ratio, Resistance to Countermeasures, Navigation, Destructive Power, Accuracy, and Conservation of Resources Need to Increase the Transparency of Sea Water for Surveillance	Technology as above Economic as above	Same as above Technological Breakthrough in Making Sea Water Transparent to Some Form of Active Surveillance Mechanism, e.g., Electromagnetic or Acoustic Radiation

FIGURE 2-3: TAILORED FORECASTS FOR UNDERWATER ACTIVITIES RELATED TO MILITARY SYSTEMS

OPERATIONAL SYSTEM COMPONENT: OBJECTIVES

BASIC CONCEPTS	KEY DRIVING FORCES	BARRIERS	OBVIATING FACTORS
Deterrent Parity Defining Threat	Traditional School of Strategic Thought, With Argument: Who is Most Powerful Potential Enemy?	Artificiality and Weakness of Almost Any "Limits" That Might be Conceived to Bound Conflict Between Nuclear Powers	International Agreement, i.e., LOS Success, on the Marine Environment and Its Resources
Determining and Developing Parity Capabilities	What are His Weapons?	Caution, i.e., Reluctance to Invest Extensively in Resource Development in the Marine Environment Without International Safeguard	Emergence of an Inexhaustible or Near-Inexhaustible Energy Supply, Such as a Technological Breakthrough in Application of Fusion Power Derived From Sea Water
Show of Power Visible Forms	How Many Does He Have?	Extremely High Risk of Military Escalation	Achievement of Territorial and Other Desired Resource Acquisitions by Other Than Military Means
Declared but Not Visible Forms	That's How Many We Need for Parity	Aversion to Negative Reaction in World Opinion	Reduction of Perceived Threat Through Other Than Military Means
Logistics Transport/Support Mode Selection—Air, Surface, Subsurface	Capability of Superpowers to Bring About Mutual Destruction		
Means of Achieving Security of Transport/ Support	Initimidating Effect of Attributed Power		
Territorial Defense/Security Establishing the Perimeter Continental, Outlying Territory, Allied Territory, Seaways	Technological Expectations re Capabilities & Limitations in Each Medium		
Defense Against Overt and Covert Operations	Current State of Investment of Resource Wealth of the Marine Environment		
Offensive Operations Against U.S. Enemies Determination of Strategies and Tactics, Including Weapons to be Used	Drive to Acquire Marine Environment Resources as Important Components of the Nation's Resource Base		
	Third World Noncoastal States Clamor for Rights to Marine Environment Resources		
	Political Vulnerability, i.e., No-Man's Land Status, of any Investment by a Nation in Marine Environment Resources		
	Slowness With Which International Agreements Can be Expected to Take Place in Respect to Marine Environment		

The particular orientation of a governmental perception as related to underwater military activities will evolve from a complex and almost indescribable network of technological, economic, political and sociological dynamics. The required structure for analysis can be summarized in the following basic concepts.

- Policy function: Irrespective of whether military capability provides a key role, minor role, or no role as an instrument of national policy, there are different contenders for social/political concepts and systems at all points of the spectrum
- Sovereignty: Irrespective of whether military power or military-like capabilities rest with nation states or within international or world government, contenders and advocates from all shades and viewpoints will exist.
- Arms: Effectiveness of arms control and disarmament vs the continuation of the need for further arms/weaponry development.

Since the advent of atomic weapons, it has been increasingly proclaimed that war is no longer an effective means of resolving disputes among nations. This argument has been extended to the proposition that military capabilities are essentially outmoded. There are extensive forecasts which indicate why it is essential to disarm the world before man destroys at least contemporary civilization if not all of life. Other forecasters contend that defensive measures can and will keep pace with offensive weaponry, and that the nature of war and military operations may change but that they are inevitably a part of the fabric of a national reality.

Some advocates state that as the bipolar control of world actions erodes and the effectiveness of the nuclear deterrent becomes more questionable, as the need for conventional capabilities within the overall massive nuclear capabilities becomes more pronounced, and as the world nations who have the capability of arming and conducting military operations of various kinds expands, the demand grows for some form of world or international government into whose hands the command and control of such capabilities will reside. Others contend that national interests demand that such control not be relinquished. Still others contend that given the nature of man and the history of nationalism, the practical reality of world government or even international governments of the type hypothesized can not be realized.

While many policy strategists contend that effective arms control and even disarmament is the safest and most needed course of the future, few now see a realistic basis for believing it will come about except in a few specific areas such as large-scale nuclear delivery systems.

Economic Capability

The type of military activities which any government can pursue are closely determined by economic capability. The economic capability is, in turn, determined by factors such as the stage of development, the level of technology and the degree to which priority for military expenditure replaces other national

- The contention that military capabilities are a necessity vs. the contention that they are a "luxury."
- The contention that military expenditures are a stimulant to economic development vs. the contention that they are a drain on economic development.
- The contention that the allocations to military expenditures should be limited by determining a maximum percentage of the national GFP vs. the contention that military expenditures are determined more by what is required to retain relative superiority.

The U.S. will have to confront such issues in constant policy debates throughout the 1980s and 1990s. Other nations will also be involved in selecting which of these concepts will govern their military actions and development.

Technological Capability

Closely associated with economic capability, is the issue of the technological capability which a nation possesses to support specific military related technological applications. An historical perspective of military operations shows that these have been very technologically intensive. Innovations have come in a constant stream, from the invention of the sling to hurl rocks, bows and arrows, steel bladed swords, gunpowder and guns right through to MIRV and CRUISE missiles. The history of warfare is replete with victories won by the side possessing technologically superior weaponry.

The two most basic concepts, from a national standpoint, which determine the technological support base of a nation are:

- The degree to which the national economy will be technologically intensive and innovative
- The degree to which the nation's goal is to be a leader or an imitator of technological development and the degree to which any such leadership or imitation is to be general or industry specific.

Generally speaking, the Western cultures have been more technologically intensive and the U.S. has long sought to lead in technological development across the entire spectrum of technology, especially military technology. This leadership is now being challenged by a growing number of nations in a growing number of fields.

Also being challenged is the nation's continued commitment to generalized technical leadership. There are those who contend that such a strategy is no longer economically sustainable, and that it should be abandoned. Evidence exists which shows that the overall national support of basic research has actually declined in real dollar terms for several years, and that this in turn spells a loss of leadership in at least some critically important technical areas.

General Societal Support/Capability

The overall support and capability of the nation's populace underlies and supports all of the above concepts. The nature of national goals, military structures, economic allocations and technological bases are all ultimately determined, at least in democracies, by this general support of the population Many concepts with varying prospectives exist. Among those most relevent to the purposes of this forecast are:

- The contention that national security should be independently maintained whether or not other "free nations" sustain their part of the responsibilities.
- The contention that security of the "free world" is dependent upon all "free nations" carrying an equitable share of the military capability load and that any gaps arising from defaults on the part of some nations must be lived with.
- The contention that military capability is no longer a road to security, and that a nation and the world are more insecure because they possess such capability. This view is close to the world government viewpoint discussed under the above section on governmental structure.

- The type of security which is sought may be conceived of as a security only sufficient to protect the national boundaries or a security which sees national protection as closely intertwined with international patterns of aggression and military action.
- The degree of passivity which is accepted as a national position. This concept originates from the moral rightness of passivity and the immorality of war, and can help shape the level of military capabilities.

Today's political struggles within the U.S. reflect varying degrees of all of these concepts. There is no indication that they will waver, nor that the debate will be less stringent in the years ahead.

Defining Required Military Capabilities

Underwater military activities are a functional aspect of overall national military capability. The potential to develop total military capability is dependent upon a variety of national political objectives and concepts including:

- The role the nation wishes to play within the overall scheme of world powers.
- The assessment of how much power other nations possess and of what they intend to do with such power.
- The interdependency of national economies in terms of raw materials, potential allied groupings and pooling of military capability.
- The concepts of what represents security in the sense of strategic or retaliatory military capability and general vulnerability of the nation's economy, infrastructure and population.

The national defining of military capabilities is a very dynamic area, and seems destined to remain so throughout this forecast period.

Assessing the military capability of other nations is so central to this analysis that it deserves special attention and further elaboration. Popular terms describing this concept are "Nuclear Parity," or "Strategic Parity" or "Military Parity." The essential idea is that since the U.S. is not seeking to be an aggressor the level of U.S. military capabiliy is determined only by our need to be at parity with or superior to other nations who are a potential threat to the U.S. Thus, the military capability is seen as an essential deterrent whose greatest value has been demonstrated by the fact that large scale deployment has not been needed.

The processes of defining military capability of other nations are not exact sciences. Careful estimates of all forms of present and future personnel and hardware are essential to the process. The various forms of weaponry which a nation may possess or develop are discussed in Chapter 3 under the heading of "Antisocial Technologies." Conceptually speaking, these technologies are available for application by either military or nonmilitary forces and hence may be military or nonmilitary activities. The reader might wish to skim the categories of such technologies now (see pages 3-4 and 3-5) remembering that their application can be in greater sophistication and scale if employed through an effective and powerful military organization.

The nature of the threats to be dealt with, from both a military and a nonmilitary aggression standpoint, are determined by the state of the technological arts of all forms of delivery of destructive capability.

Once the potential threats of nations has been determined, the next step is determination of the potential defensive capacity of other nations and of the U.S. This process provides general estimates indicating the level of military capability which is needed, and begins to define what specific portion of the military force structure is in need of attention.

As will be shown later, these processes will soon begin to result in gradual but growing policy shifts that will place underwater military activities into a greater position of importance within the national defense posture.

Developing Needed Military Capabilities and Operating Them

Within Figure 2-2, development and operation of the military capabilities are shown as separate processes. This is indeed the case. But the technological concepts are so closely related that they are combined for purposes of description and discussion.

Some of the more general technological areas of most significance to underwater military capabilities and operations are discussed below:

Functions of surveillance, detection and identification

Relevant technological concepts include:

a. Increase in acoustic and electromagnetic power radiation
b. Improvement in electromagnetic and acoustic signal analysis
c. Data processing
d. Improved satellite capability

e. Over-the-horizon (OTH) radar technology

f. Sea water "window" research

Increased power radiation will continue to be a "brute force" means of improving surveillance and detection capabilities. It is invariably accompanied by increases in the size of the platform from which the radiation takes place. The incremental utility of increased power radiation will continue to decrease to the end of the century, especially beneath the sea surface.

Improvements in signal analysis capability will improve ability to descriminate targets from noisy backgrounds both above and below the sea surface, with both active and passive radar and sonar techniques.

Advances in data processing technology will enable surveillance techniques to handle masses of targets simultaniously. Electronic display techniques will permit the elements of a military unit to observe the results.

Special signal analysis techniques will improve satellite surveillance of the sea surface and will increase satellite capability to detect subsurface activities and foreign objects.

Research will lead to exploitation of ionosphere bounce techniques to improve OTH radar capabilities which will add to our overall surveillance capability.

Attempts to discover a sea water "window" through which some form of radiation may become observable will continue with only slight probability of success, but with some small incremental increase in our surveillance capability. Associated with this research will be an effort to discover some form of impedance matching mechanism with which to detect acoustic activity below the sea surface from stations above the surface.

Functions of localization and tracking or functions of mission/target identification

Relevant technological concepts include:

- Improvements in bearing, elevation and discrimination characteristics - both electromagnetic and acoustic; and improvements in range resolution characteristics of echo ranging devices.
- Improvements in predictive computational techniques - using second and higher derivations of target motion - in order to improve both weapons intercept accuracy and fidelity of tracks.

- Improvement in ability to track against and through noisy backgrounds.
- Improvements in capability to track large numbers of targets simultaniously.
- Improvement in ability to accommodate to changes in medium characteristics - i.e. changes in sea water temperature, and therefore changes in refractive and reflection characteristics.

All of the foregoing improvements will contribute to increase in ability to pinpoint the location of targets and to maintain up-to-date information on their movements, despite large numbers of targets and despite interfering radiation and reflection.

Functions of command and control

a. Subsurface operating coordination

b. Inertial navigation

Communications technology will continue to improve command, control, and coordination of operating units from remote command sites in two major respects: Control of air, surface and subsurface operations, and reduction of response time against threats in all environments. Satellite communication technology will play a major role.

Coordinated air/surface-ship/submarine operations will continue, but with an increasing role for the submarine as command and control capabilities improve.

Inertial navigation technology will improve navigation of vessels of all sizes on, above and beneath the surface of the sea. As activity beneath the sea surface increases, the need for installing navigational systems in that region will increase. Advances in inertial navigation will find broadening opportunities.

Functions of transport/delivery mechanisms

Technological advances relevant to weapons transport/placement vehicles is leading to developments in a number of areas:

a. Microminiaturization of electronic components.

b. Sophistication and complexity of electronic components

c. Submarines

d. Mines

e. Individual/team operations

f. Logistic support

g. Hydrofoils

h. Air cushion vehicles (surface effect ships).

i. Verticle/short take-off and landing (V/STOL) aircraft

j. Near-invisible electromagnetic and acoustic hull coating

k. Vessels with near-indiscernible magnetic and acoustic signatures

Microminiaturization of electronic components promotes modularization of components such that the basic missions of vehicles may be changed by substitution of modules. It also promotes reduced size of vehicle, giving rise to increasing use of remotely piloted vehicles (RPV's) in the air, on the surface, and to a lesser extent, beneath the surface. These RVP's may be programmed and guided, and used for surveillance as well as for weapon delivery/placement.

Sophistication of electronic components leads to improvements in surveillance, detection, tracking, and command and control to counter the threat of small missiles against surface vessels. However, this sophistication promises to continue to increase equipment complexity and represents a counter-trend to that of microminiaturization: the more sophisticated equipment tends to be less rather than more susceptible to modularization and easy substitution of modules.

Advances in submarine technology will enhance submarine superiority over the surface vessel as a weapon system transporter and launcher for at least the remainder of the century. By the end of the century there will be interest in surface craft with capability to submerge to shallow depths for short duration at slow speeds for concealment purposes.

The technological base for highly sophisticated military mines will grow. This base will provide the potential to develop mines which propel themselves, are remotely controlled, bury themselves in the sea bed and attack selected targets, and are activated and deactivated from external control stations. Through sensitivity to combined electromagnetic, magnetic, and hydrodynamic signatures they can be virtually sweep-proof. The potential will exist to develop nuclear powered mines which patrol specified regions for long periods and attack selected targets, or automatically deactivate upon expiration of their propulsion power.

Individual divers and teams of divers will find greatly expanded uses, including maintenance of underwater military facilities and equipment, handling of tactical weapons, and surveillance patrols of underwater regions. There will be an improved diver capability to descend to lower depths, to remain submerged longer, to dive or ascend rapidly, and to operate under a variety of adverse circumstances.

Underwater logistic support capability will increase significantly. Underwater mass transport submarines will begin to make an appearance before the turn of the century. They will be able to transport troops, supplies and equipment more cheaply and more securely than by air. Underwater maintenance vessels will service both the underwater installations and the underwater operating units.

Continued development of the hydrofoil and air cushion vehicle concepts will extend through the remainder of the century and result in a significant increase in the number of such vehicles in operation in the military forces. They offer the advantage of high speed and greatly reduced vulnerability to submarine weapons and to the antiship missile.

Development and proliferation of V/STOL aircraft will continue and will increase at least slightly the capability of units above the surface against units below the surface.

Slight advances may be anticipated in technologies to reduce the detectability of units below the surface. These are principally in hull coatings to reduce electromagnetic and acoustic visibility and in propulsion and hull design to reduce magnetic and acoustic signatures.

Missiles are a growing part of underwater military capabilities. The technological concepts related to missiles are:

a. Increasing weapon power-to-weight ratio
b. Improving propellent capability
c. Improving guidance capability
d. Improving fusing capability
e. Using mammals

Technological advances in the first four areas listed above lead to more accurate delivery of a given destructive power at targets at greater ranges, with greater reliability, and with higher kill probability due to more reliable fusing These advances apply to short range and long range missiles, projectiles, depth charges, shells and hand weapons. They apply to anti-personnel, anti-aircraft, anti-ship, anti-shore, and ASW weapons. Advances in signal processing lead to improvements in guidance, discrimination and fusing in smaller packages; advances in combinations of electromagnetic techniques - visual, IR, laser, X-ray, UHF-VLF, radar-magnetic techniques, and acoustic techniques lead to additional improvements in guidance, discrimination and fusing, including defense against countermeasures.

The promise of using marine mammals will continue. More species and greater quantities of marine mammals will be used for spotting, for protection of divers, and for the various types of uses now conceived. Mammals will be equipped with internal explosive devises which can be triggered from a remotely controlled operations center. Such delivery systems will be virtually indistinguishable from natural movement. These will present major defense, surveillance and tracking problems. The range of uses to which mammals can and will be put will increase. The equivalent of guard dogs under the sea will likely emerge in at least some highly concentrated areas. These mammals, armed with sensors, will make excellent observation units and their cost would be less than submarine deployment.

Payloads

The ultimate purpose of all underwater military operations is to deliver certain forms of payloads if, as and how they are needed. The "payload" is the direct instrument through which the destructive power is exerted. They may be any of the antisocial technological devices within the various categories of technology discussed in Chapter 3. The payload device, in terms of size and scale, is integrated with the delivery systems/devices discussed above. The most general trends within payload technologies are:

- Greater precision of destructive power such as the ability to destroy life but not buildings with neutron warheads or payloads.
- Greater power per weight ratios, making it possible to package the destructive potential in many different ways, shapes, forms and sizes.
- Greater control over detonation from remote controls as opposed to depending upon the "strike" to trigger the detonation.

Assessment

The same technologies and concepts discussed under surveillance, detection and identification and under command and control will provide the basis for improved instruments of assessment.

Self protection and recovery

The technological bases for these functions are also intertwined with the various technologies already discussed.

Logistics

Underwater habitats of long endurance capability are becoming feasible. It is thus possible to establish underwater military bases both on the sea bed and beneath it, some fixed, some quasi-fixed, some mobile. Bases beneath the sea bed will be acoustically invisible. These underwater bases can provide support for extensive operations, both in the marine environment and beyond it. ICBM tubes can also be embedded in the sea bed.

Deterrent parity

(Already discussed in connection with defining needed military capabilities. See pages 2-15 and 2-16.)

Show of power

A long standing and effective use of military capability is to produce a highly visible "show of power" within geographic areas where the political negotiations are served. Placement of U.S. carriers in the Mediterranean area as negotiations or threats to various policy objectives within that area are commonly known examples. However, many of the most potent current capabilities cannot be so mobile. Aircraft can perform "fly overs" but permanently placed ICBM's in silos cannot be transported to show force.

Underwater military capabilities are also likely to be of a nature which will make a conventional "show of force" role difficult. Many of the capabilities will be such that their secrecy is important to their effectiveness.

Nevertheless, the overall underwater military capabilities will be an important part of the overall capacity. Their deterrent value will depend upon having at least some credibility to the fact that they exist and can do what is expected of them.

Logistical transport and support

(Related technological concepts are discussed in the forthcoming section on transport. See Chapter 7.)

Defense/security U.S. territory

The particular territorial defense objectives change from time to time. The homeland is the minimum geographical area of concern. But to this area may be added U.S. territories and possessions and the homelands of U.S. allies. Nations whose security is considered essential to the U.S. security, such as bordering states of Canada and Mexico, are often included within the U.S. defense concerns.

The problems of defending against both overt and covert operations in times of both declared and undeclared hostility up to and including all-out war present important complicating factors. It is no longer so clear cut as a condition of war or peace. Force must be applied selectively within the context of a growing variety of international relationships short of declared hostility, or various forms of declared hostility short of war.

Key driving forces, barriers and obviating factors

The key driving forces, barriers and obviating factors which will ultimately determine how the above technological concepts are developed and employed are outlined in the designated columns of Figure 2-3. They are sufficiently self explanatory to not warrant further description here. More discussion on them will follow in the tailored vignette.

TAILORED VIGNETTE

The Role and Nature of Military Power

Ultimately, the nature of underwater military activities will be determined by the role and nature of military power, i.e., how it is used by the types of government and the specific operational capacities it represents. It is therefore of foundational importance to a forecast of underwater military activities that a forecast first be developed of the role and nature of military power.

At its most fundamental level, operational military power may be defined as the level of destructive capability which a nation's military forces can wield in given circumstances and against given opponents. In this analysis, such power is termed "antisocial technology." This term does not imply that military forces are antisocial; indeed, from the viewpoint of the security of any nation, its own military forces are very essential and positive social instruments. Neither does the term antisocial technology imply that the undergirding technologies which make modern destructive capabilities possible are antisocial. Many such technologies can be used for the most humanitarian of purposes. However, it is useful to employ the concept of antisocial technologies as a convenient framework within which to discuss overall military capability and threats to property and life when such threats are the result of deliberate human action with the intention of destruction or harm. In the military realm these range

from hand-to-hand combat in which individual prowess and skill and numbers often are the determining factors to long range nuclear devices which can destroy all life and/or property for many square miles.

Those antisocial technologies considered relevant to this analysis are classified into seven categories which are defined in more detail on pages 3-4 and 3-5. (It is suggested that these definitions be read now.)

The most critical determinants of the role and nature of military power are a combination of complex and somewhat poorly understood psychological, social, political, economic, and technological factors. However, for purposes of this analysis, the most critical questions concern:

- Whether there will emerge an effective concept of arms limitation, the nature of such limitations and the degree to which destructive capability resides within the responsibility and control of sovereign governments
- The role which the U.S. and other nations will see for themselves in terms of overall world military power and capability, and in terms of their own national military capability
- The political, economic, and social will and capability to sustain various forms of military power
- The technological and social developments which will determine the immediate operational military capability of the U.S. and other nations.

This section addresses these foundational forecasts.

Despite the growing talk about "one world" and the drive to develop a "one world economy" and a "one world system of government," national sovereignty will remain as the dominant feature of international governmental structures. Nation states will relinquish such sovereignty only in highly selected and specialized circumstances, and then only to the degree and for the time which they perceive such relinquishment to be in their own best national interest.

For several decades many western intellectuals have advocated the need to perceive that the era of the nation state and concepts of national sovereignty in many areas of world affairs (especially in the possession and use of military forces) must be supplanted by some effective form of world governmental structure. Such structures generally would relegate to an international or world governmental institution certain powers in a similar manner now employed between the various states and the federal government within the U.S.A.

Intellectual and political leaders of other cultures have contended that a one world government is indeed desirable, but that it should be achieved through world conquest.

Still others contend and act on the premise that enlightened interest is important, but that in the final analysis the nation of which they are a part is the highest sovereign allegiance for which it is reasonable to be committed. The League of Nations and the United Nations are the most notable modern attempts to operationalize some form of effective international/world governmental structure. Since the formation of the United Nations, we have seen nationalism rise rather than fall. The ending of the colonial era has brough forth many new nation states, and with few exceptions, the older nation states have continued to perceive themselves as sovereign powers and are unwilling to relinquish sovereignty to a world government structure. We see no reason to believe that these deeply held values will shift to a degree as fundamentally to change this situation during the next two decades.

Another dimension of effort along the lines of achieving world order and the "effect" of world government has been to rely upon a network of international agreements and a balance of overall military power/capability largely restricted to two major power blocks led by the United States and the U.S.S.R. This arrangement came to be conceptually formalized by the term "a bipolar world." Since the advent of nuclear power and the cold war arms race dating from the early 1950's, this rather informal arrangement has been seen as the principal instrument of world order. In this type of arrangement, the U.S. has seen itself as a major world power responsible to be the leading power of the "free world." In general, required levels of military power have been defined as a determinant of what was estimated to be the capabilities of the U.S.S.R. and of other defined potential opponents.

Until the 1960's, there was little significant challenge to the proposition that the U.S. carry the major responsibility for military development and capability even in collective regional security alliances as the North Atlantic Treaty Organization and the Southeast Asia Treaty Organization. Thus, the nations of the world gathered largely under the collective "nuclear umbrellas" of the bipolar world.

The early contentions that such an arrangement could be effective through only the retention of "strategy parity" which was actually more properly conceived of as "nuclear parity" were soon frustrated. The proposition that the

nuclear age had rendered war to be an ineffective means of securing national objectives, and that war could be averted by the clear superiority or bipolar parity of strategic (primarily nuclear) arms soon was replaced by the concept that a nation having only the nuclear capability of total destruction which could not be used was not secure, because it could not defend itself along the entire range of military capabilities. Hence, the U.S. strategy shifted to one of balanced force mix in which conventional and nuclear and other capabilities were retained along the entire operational continuum of antisocial technologies which were likely to be employed against the U.S. or its allies.

Recently, it seems clear that the bipolar arrangement as a means of governing world order is eroding, and that a more diversified multipolar world is becoming a reality. The particular alliances and power blocks which ultimately will comprise the important nuclide of this multipolar world are not yet clearly defined. It is most likely that these lines will remain hazy for sometime to come. But it does seem clear that the drift toward a multipolar world is more prevalent than is the drift toward a unified world government.

It is our view that the network of dynamics underlying these overall trends and developments will continue to function toward national sovereignty and selected collective pacts of nation states rather than toward relegation of sovereignty into a formalized world governmental structure.

As the multipolar world emerges, there will be a general proliferation of world military power. The "nuclear monopoly" will be eroded in two senses: the proliferation of nuclear power itself, and the emergence of a variety of other forms of antisocial technology which can give nations the equivalent destructive effectiveness of nuclear power. This latter situation might be termed the emergence of "non-nuclear strategic parity."

One of the key driving forces to the multipolar trend is the emergence of former colonial territories as nation states coupled with the fact that more nations are moving further up the scale of economic development. The fact that the world's basic supply of natural resources is dwindling in some of the more advanced economies requires these nations to increasingly procure such resources from the less developed economies. Petroleum is but the better-known example of a growing list of these resource dependencies of the advanced economies, especially of the U.S., Western Europe, and Japan. These trends are giving many nations a new

means of actually converting their resources to cash flow, or effectively capitaliaing their natural resources. These nations are, in turn, interested in acquiring military capability along with their economic development. Thus, we find an overall worldwide trend of an arms' industry growing as a major economic sector in more and more countries. Therefore, the world arms are proliferating both on the supply and consumption spectra.

Concurrently with these developments, the technological monopolization is eroding the most important technologies. This monopoly accrued naturally because the developments were at the leading edge of the technological arts and were known and knowable by but a few leading experts in the countries developing these capabilities. More and more of such capabilities are now a normal part of the technological arts, and they are known or knowable to more and more persons who are technically qualified.

If one perceives military parity as the capability to render mutual levels of destruction up to an including the destruction of an opponent's economic, social, and physical capacity to exist as a nation state, then there are an increasing number of ways such power can be acquired. Thus, the nuclear monopoly as the sole instrument of world strategic parity is eroding. For years there have been other alternatives, but they have not had the visibility. Chemical and biological concepts of warfare and antisocial technologies are already capable of development to points whereby they can represent at least the equivalent of nuclear capability. Such agents of destruction can be developed and delivered less expensively and more clandestinely. The affixing of responsibility is more difficult, and in some cases impossible.

While there will be limited success in specific arms limitations, there will not be a successful and effective structure which will reverse the above above proliferation of military capability. The military capability proliferation will continue not only in terms of the number of potential actors, but also in terms of the range of potential actions which may be taken.

Current agreements among the USSR, the U.S.A. and other leading nations ban further development and production of certain forms of chemical, biological, and nuclear capabilities. International agreements are enforceable only so long as all parties continue to see that it is in their best interest to continue as a party to the agreement. In general, the history of international pacts has not been one of long-term success. Given the fact that all nations of the world are not formally included, and that some of these nations are likely to be interested in some form of "nonnuclear equivalent" to strategy parity, and that

nuclear arms of the large-scale mass-destruction type may be somewhat limited, and that this in turn may release resources for development of other alternatives, it seems that the only real hope for a reversal or arrestment of the overall arms race is a worldwide voluntary abstention. So long as any nation continues to push its military capability ahead of others, there will be a continuation of the arms race in some form. The next plateau of the arms race is already outlined. It will involve much more powerful weapons (qualitatively so) across a much wider spectrum of operational capability (see Chapter 3 on "Antisocial Technologies") deliverable in much smaller increments or packages and in a much more diverse number of ways.

The U.S. will continue to see itself as needing to fulfill a role as a leading world power, and as needing to retain an effective and powerful military capability as a deterrent to aggression or as an effective defense against aggression at every level it is likely to be encountered. This means a combination of defensive and offensive retaliatory capabilities will be sought which will be second to none in the world. The emerging debate of whether the USSR is achieving military superiority over the U.S. is a manifestation of the fact that the U.S. perceives this trend as an important aspect of national policy. Given the preceding forecasts of the nature of overall structures through which to impose or fail to impose world order, we see no reason to believe that ultimately the U.S. will not continue to see a need for overall military parity.

The techniques for calculating parity will continue to be expanded to incorporate overall "military parity" at various points of the spectrum of military operational capabilities. This will lead to the ultimate decision that the U.S. must remain effective against any and all potential enemies and to be able to recounter at any point of the spectrum. The result of this concept and definition of parity is already in effect in the current concept of balanced forces not only in terms of air, sea, and land capabilities but also in terms of conventional and nuclear or strategic warfare capabilities. As the range of potential enemies and their scale of operations is broadened, then the implications of these definitions will become more significant.

Thus, the U.S. will continue to see the maintenance of military capability to be an important instrument of its own national policy and security as well as that of her allies and of the world in general. Although the actual employment of such capabilities may become more cautionary and reluctantly used, the capability for employment will be a continuing high national priority. The

determination of the required level of capability will primarily evolve from the application of the concept of "military parity." There will continue to be hot national debates over the relative allocations of the nation's economic resources between military and nonmilitary or defense and nondefense. But in the final analysis, the principal criteria for determination of the economic resources to be allocated to the overall defense capabilities will be the perceived threats to national military security and the defined capabilities necessary to encounter effectively such threats. It seems most likely that future developments will result in rather significant increases to the current levels of military expenditure. The political dynamics of the U.S. will swing toward making such allocations even if they represent significant proportionate increases in the defense segment of the GNP. In terms of the economic well-being of the general populations, such expenditures will facilitate employment, technological advances and development, and overall economic stimulation. These expenditures also will require that shifts be made in other national priorities. In the final analysis, in the mid-to-late 1980s, the threats of a lag in military capability will be perceived in a general popularistic manner; the gap in such capability will be more precisely defined and seen to be a clear and present danger. These are historically, and will continue to be, the key factors to mobilizing the political dynamics which will result in the needed priorities to amend any military lag.

This forecast also is based upon an underlying forecast about the strength of the U.S. economy. *Even though there will be shifts, the U.S. economy will continue to be one which is sufficiently strong to underwrite the needed military capability. It will continue to be technologically intensive in character (discussed in various detail in subsequent chapters) and it will continue to be one in which overall technological leadership is seen as a cornerstone of national development and the retention of continued economic development in both a qualitative and quantitative sense.* There are further details on these basic issues in subsequent chapters. The current debate over the degree to which technology enhances or impairs quality of life will continue and will affect the way in which future technologies develop. Technological assessments will grow and be used in an increasing number of ways. Arguments that the world should disarm itself and in fact should deindustralize itself or at least arrest the exponential curves of growth now being experienced as a result of industrialization will also continue.

But there are no basic indications which would lead to a persuasive case that these arguments will result in any significant changes within the structure of technology and of economics. The reasons are outlined above for how the ultimate results will emerge in the area of the role and nature of military power.

The Role and Nature of Underwater Military Capability

Within the overall framework developed above, it is now appropriate to turn to a more specific and direct examination of just how underwater military capabilities will fit.

The overall importance of military operational capabilities within the marine environment in general and with the underwater environment in particular will increase. The need for securing supply lines for critical resources flowing from among nations separated by seas and oceans is growing and will continue to grow. The complexity of securing such supply lines is also growing and will continue to do so. The vulnerability of and expense of delivery systems for land-to-land intercontinental weapons also is growing and will continue to grow. These and related trends and developments which they stimulate will result in an expanding demand for the range and type of military capabilities within the marine environment and within the underwater environment.

It seems clear that future technological developments will change some fundamental doctrines of marine-based military capabilities which are cornerstones of current U.S. strategy and planning. Some of these shifts will emerge in terms of increasing ranges and scale and type of military capabilities needed within the marine environment. The others will be of a type which will tend to make the underwater military capabilities a much more important component of the overall force balance. *Effective antiship missiles and comprehensive surface surveillance systems will move into the state of technological capability and will be clearly demonstrated.* The results of this development will be a profound reassessment of the security and effectiveness which can be afforded by a navy based essentially upon a surface operational capability. This reevaluation will extend to the security which can be achieved for the transport of critical military supplies, personnel and materials via water if that transportation is attempted in surface vessels. A combination of surveillance capabilities plus destructive devices capable of total vessel destruction (such as small nuclear devices or their equivalent) deliverable in a variety of relatively low-cost

and highly effective network and alternative delivery system options will converge to make this reassessment become a matter of major national debate. The information will be commonly known and the debate will not be restricted to the Pentagon or legislative and executive branches.

Underwater alternatives to surface operations are increasingly evident in terms of forecasted technology which would be possible to develop. Large submarine cargo carriers operating at greater depths and over long distances and the entire range of technologies discussed elsewhere in this chapter illustrate the point. The underwater area will continue for at least several decades to offer both a more effective "protective cover" and a more defensible mode of operation.

Given these technological opportunities, which will become much more clearly defined by the early to mid-1980's, some nations, including the U.S., will begin to place a high priority on developing their underwater capability. This development will act to stimulate a new and major sector of the arms race, i.e., the securing of military superiority and parity will be seen as requiring such superiority and parity of military capability within the underwater environment. The ultimate result of this will be that *traditional naval strategy and tactics will shift from primary reliance upon surface based military capabilities to primary reliance upon underwater military capabilities for security against those opponents capable of threatening offshore resources and economic operations and also for the effectiveness of the more traditional naval role of securing the sea lanes for transport and conducting tactical operations.*

Despite the overwhelming force of logic in support of the shift of primary reliance upon surface forces to reliance upon subsurface forces, two very powerful factors will inhibit this shift. The first is pragmatic; it includes the high resource cost of vehicles capable of subsurface operations, and the technological difficulty of command and control of forces operating beneath the surface. The second inhibiting factor is less tangible; military tradition which will continue to exert pressure toward "conventional" air and surface forces; the conventional wisdom of federal politics in the executive and legislative branches which can be expected to resist so drastic a change; and, overlaying both of these, the psychology of sunk costs which will exert resistance against "wasting" resources already invested in the more conventional force structure.

The effectiveness of the antiship missile has driven the U.S. Navy into a large-but-few vs. small-and-many dilemma with respect to its composition of combat units. The high cost of production further exacerbates this dilemma. Miniaturization and microminiaturization technologies have led to the capability to package highly effective systems into relatively small units, but at a cost which limits the number of units. Thus, the convergence of these forces, plus pressures described in the previous paragraph, are forecast to lead the U.S. Navy to an overlapping step as it begins to acquire the major portion of its capability as a subsurface force; this is the acquisition of additional surface forces of reduced unit size. This investment over the next several years may further delay acquisition of the optimum force composition--the subsurface operating force--because, again, of the inhibiting effects of tradition and sunk cost psychology.

As is discussed in more detail in Chapter 3, the problem of discriminating whether a threat is present, and whether the threat has resulted from a foreign military or nonmilitary source will become an increasingly intractable problem. In an increasing number of areas there ultimately will be a merger of operational responsibilities for some areas of protection and surveillance which have characteristically been much more clearly definable as either military or nonmilitary in character.

It is against this overall backdrop that the forecasts related to specific underwater military activities must be developed. The following paragraphs now turn to how we expect these specific activity areas to emerge.

<u>Submarines as Weapons</u>

When the evolution of naval forces has reached the stage which we have forecast in the preceding paragraphs, we may expect the number and types of military submarines to be increased significantly. We foresee the following general types in operation:

- Strategic Long-range Ballistic Missile (SLBM) submarines with greater depth, range, firepower, sea-keeping ability, and manpower efficiency than today's SLBM submarine, but otherwise of the same general characteristics.
- High-speed, deep-diving attack submarines with increased firepower for use against both surface ships and submarines
- Smaller special purpose submarines of shorter range and with somewhat less firepower utilized in shallower waters over the OCS in defense of U.S. assets in the subsurface region of the marine environment. There may be several varieties of this type to conform to the specific requirements and configuration of U.S. assets. Some may be primarily for patrol and surveillance, some may be equipped to intercept covert entrance into a

region, some may be configured with heavy firepower for perimeter defense, and some may be specially fitted to neutralize terrorist or other smaller scale antisocial intrusions

Technological advances will lead to increased effectiveness and efficiency in all of these submarine types. Ultimately a command and control network of high effectiveness in the subsurface region may be developed which overcomes the opacity of sea water to the mechanisms of surveillance (see subsection below on "Underwater Installations"), but this will not be beyond its early stage by the end of this century

Operational demand will promote development of at least prototype craft with capability to operate effectively beneath, on, and above the sea surface.

By the end of the century only the more technologically advanced nations will have acquired even prototypes of the sophisticated vehicles described above; however, many nations will have acquired the capability to operate divers and teams in and with small submersibles in the relatively shallow waters over the OCS, and in the regions in which entreneurship has established resource exploiting assets. These developments are discussed below.

Mines as Subsurface Weapons

By the end of the century, technological improvements in subsurface surveillance and command and control will not have advanced sufficiently to permit discriminatory and selective control of mine detonations. This means that mines will be used only in waters prohibited to our own forces. A nation may decide to use mines to deny access by other nations to their regions and their resources. Thus, *mine deployment will be attractive to Third World nations without capability to develop subsurface resources of their own, but with motivation to prevent resource development by others, or to destroy subsurface assets already in place.*

The types of mine potential payloads include:

- *Moored mines of the conventional type*
- *Self-propelled mines which activate from either a mooring or from beneath the bottom*
- *Wire-guided mines that either home on targets or are guided*
- *Mines with conventional, small nuclear, chemical, or biological payloads, or some other form of destructive agent*

* *Mines which rely on natural forces for delivery--such as ocean currents, wind, or a combination of these*

Individuals/Teams

As the subsurface complexes of assets devoted to resource extraction and exploitation grow, individual divers and teams of divers will be used in an increasing amount. Diving equipment and diver capability also will be significantly improved to enable diving to greater depths, with more flexibility of movement, and increased capability to operate in adverse weather and sea state circumstances.

Divers and teams of divers may be expected to operate from underwater installations and perform a variety of functions, including:

* Surveillance
* Security patrols
* Maintenance and repair
* Law enforcement
* Communications between underwater installations

Underwater Installations

At least some underwater installations may begin to appear. They will be a combination of fuel storage, weapons storage, and storage for various other supplies which will permit underwater docking for refueling, reaming and resupplying underwater operational vehicles. In addition, there may be some underwater work stations for maintenence activities and dispatch centers, for rescue dispatch, and for various other purposes.

Some of these installations may be fixed to the ocean bottom, but most are expected to be semi-fixed in much the way a house trailer is today. This mobility will permit changing patterns of defense against covert antisocial activity.

By the end of the century, the number of underwater installations will be small, but with clear indications of their potential and their probability of further growth.

By the late 1990's, it will be possible to foresee clearly a step forward in underwater surveillance and command and control capability, based upon operating units in underwater installations. Acoustic transmissions are the only

known and foreseen effective mechanisms for underwater surveillance and command and control. The monitoring of sea water temperature and salinity characteristics will be advanced sufficiently to permit computation of sound propagation behavior in a specific region. Computational technology in real time also will advance to permit prediction of sound ray and sound beam behavior, and thereby permit accurate localization of targets through triangulation from several underwater acoustic listening stations. Coded transmission of acoustic signals to operating units then will be possible and enable underwater control stations to guide submarines and other submersibles to targets, without these operating units themselves revealing their own positions.

Underwater Logistic Support

Mass transportation of troops and supplies gradually will become economically feasible, so that by the end of the century there will be clear evidence of its emergence as a vital factor in underwater activities. Underwater transportation of large volumes will provide greater security than surface transportation under hostile conditions and will be more economical than air transportation. Thus, large transport submarines will begin to be operational by the end of the century.

In addition to use of the underwater region as a transport medium, logistics activities will include support of underwater military activities themselves. *This will take place through submerged submarine tenders and supply ships capable of submerged docking and other interactions with underwater installations and craft.*

Surface and Land Based Weapons Systems Interface

The linkage between underwater weapons systems and surface weapon systems is well established now and will continue, though declining as naval forces are moved to the subsurface region.

Coordination relationships between subsurface weapons systems and land based command and control stations and land based weapons systems will grow as subsurface systems proliferate. *Land based missiles will be capable of being guided into the water to seek subsurface targets. Ultimately, missiles will be launched from land, enter the water at some prearranged distance from the target, then exit the water for final attack on targets. The sea opacity thus will be used to screen the missile during its last leg of transit toward its target.*

At some stage in future development, it will be possible to fire weapons from beneath the surface against tactical land targets, analogous to naval gunfire support today. As discussed above under "Underwater Installations," significant developments in command and control technology will be required before this can take place.

Air Based Weapons Systems Interface

In principle the same considerations apply to this interface as to the interface between subsurface and land based weapons systems. Command and control technology advances will lead to improved coordination between air and subsurface operating units.

Surveillance and Monitoring

The impenetrability of sea water to surveillance mechanisms--electromagnetic, magnetic, and acoustic--will persist into the next century and make subsurface surveillance a most challenging technological problem. Technological advances will center around the effectiveness with which sea water transmits sound, and will address improvements in the accuracy of locating targets, and in the identification of target types. Progress is forecast to be slow, but the increases in the population of underwater units will render related research of highest priority. It will be of utmost importance to detect and track every possible potential military threat that enters the region.

One of the most acute surveillance problems will be to determine that an aggressive action has, in fact, taken place. Successful covert action will be likely to mask activities in such a way as to make it very difficult to ascertain causes of damage or interference in operations.

Advances also will take place in surveillance countermeasures; decoys and other masking mechanisms will be deployed along with attack units to increase difficulty of detection and tracking.

Advances in data processing technology will permit real-time display of entire regions showing virtually all activities taking place in the region. These display systems will be placed in a wide variety of locations for use by all echelons of military command.

Research and Development

All areas of R&D related to the categories discussed above will be intensively pursued. In addition, the military R&D will be coordinated with increased nonmilitary R&D on the underwater environment.

Marine Mammals

The potential of the use of marine mammals will continue. *More species and greater quantities of marine mammals will be used for spotting and for protection of divers.*

Mammals will be equipped with internal explosive devices which can be triggered from a remotely controlled operations center. Such delivery systems will be virtually indistinguishable from natural movement. These will present major defense, surveillance and tracking problems.

The range of uses to which mammals can and will be put will increase. *The equivalent of guard dogs under the sea likely will emerge in at least some highly concentrated areas. Armed with sensors, these mammals will make excellent observation units at a much more reasonable cost than would be the case with underwater vehicles.*

CHAPTER 3: PROTECTION OF PROPERTY AND LIFE

DEFINITION

This category includes the protection of offshore assets and human life from:

- Extra-legal applications of antisocial technology from other than military agencies against nonmilitary targets. Included are such activities as terrorism and industrial, commercial and economic sabotage.
- Natural disasters such as offshore earthquakes, volcanic eruptions, hurricanes, fog, etc.
- Major accidents involving threats or damage to property and life.
- Search and rescue operations.
- Salvage activities.

Specifically excluded from treatment here, though they are a part of the overall system, are such activities as regulation, standards, inspection and related enforcement. These areas are discussed as separate activity categories.

Additional exclusions are accidents or other events resulting in pollution of the underwater environment which do not pose an immediate or highly probable lethal danger to property or human life. Polluting events as conventionally described, such as oil spills, municipal wastes, etc., are included in Chapter 8 as a part of the activities involving injection of foreign elements from man's activity.

BACKGROUND

Marine history is replete with the importance of protection of offshore property and life. Development of reliable maps and charts, of systems of navigation, of lighthouses, and of many other features of the contemporary marine environment testify to the importance placed upon this function.

The overall climate of protection will be particularly dynamic. The following major features of this climate form the backdrop against which to forecast underwater activities in this category:

- The combination of increasing offshore investments, developments in antisocial technologies, and overall political/economic developments will make the threat from nonmilitary aggression an area of rapidly growing concern.

- Improved techniques of predicting natural "catastrophies" which pose a threat, combined with the growing range of offshore activities will make attention to the effects of natural catastrophies more diversified and important.

- The increased activities plus various other developments in marine vessels will make concerns for major catastrophic accidents more prevalent.

- At least several major catastrophies will occur within the next decade. These incidents will spur both attention and concern to a higher level of public visibility and demands for effective protection. The reverberations of these demands will be felt throughout the entire range of protective functions.

FUNCTIONAL SYSTEM

The functional system for forecasting activities in this category is summarized in Figure 3-1. There are three basic components of the system:

- Objects of threat: persons, offshore property, coastal ports/personnel and inland ports/personnel
- Sources of threat: nonmilitary aggression, natural forces, accidents, and irresponsible, uninformed, or otherwise unsafe human behavior
- Systems of protection and recovery: threat recognition, definition, and assessment plus the capacity to execute appropriate responses

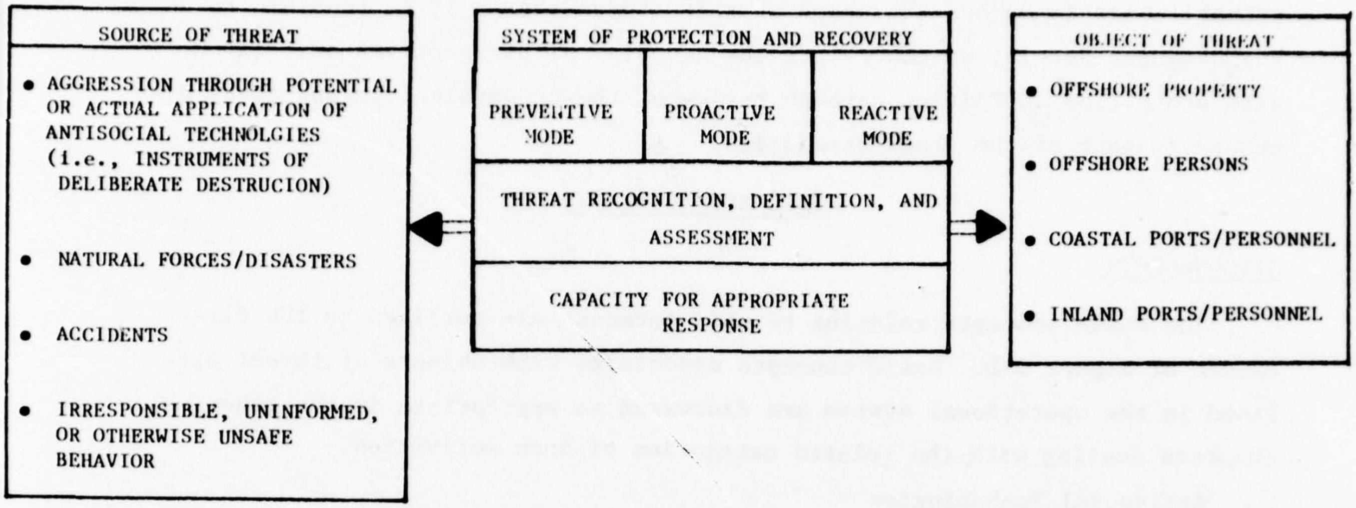
The protection and recovery of activities are executed within the context of three basic time frames:

- Preventive: steps which preclude a threat from occurring

- Proactive: steps to intercept a threat and negate any damage occurring from it

- Reactive: steps to neutralize or reduce the effects of an event which has rendered damage

FIGURE 3-1: OPERATIONAL SYSTEM: PROTECTION PROPERTY AND LIFE



GEOPHYSICAL PERSPECTIVES

There are no intrinsic geophysical boundaries to protection activities. They are required wherever objects and sources of threats may converge. There are, however, some general principles worthy of notation:

- Protection of offshore fixed facilities will be clearly definable by where those facilities become located. A review of the probable distribution of activities requiring such facilities within each of the other chapters will give a good picture as to the probable distribution of this aspect of protection.

- For some forms of antisocial technologies, natural forces such as wind and ocean currents may become a component of the delivery system. Related protection activities can be charted in terms of the geophysical patterns associated with these natural forces.

- Threats arising from natural phenomena/forces such as storms, fog, and earthquakes also are generally related to areas of higher probability. These areas are determinable either from historic patterns or from the association of the natural factors related to each type of threat. Such geophysical conditions vary with each threat, but they can be plotted in a reasonable manner.

- Salvage operations largely are limited to the areas of concentrated activity, either of fixed or mobile facilities. Transportation corridors, fishing waters, and various other locales where activities are centered are the determinant factors. Of course, random events can occur almost anywhere, leading to the need for search capabilities more usually associated with rescue functions.

The detailing of the elaborate network of threat-specific geographical probabilities is beyond the scope of this study--though it is feasible to do. For purposes herein, we can relate the geophysical perspectives associated with protection activities through review of the geophysical perspectives discussed in each of the other categories.

TAILORED FORECASTS

KEY CONCEPTS

The basic concepts relating to this forecast are outlined in the first column of Figure 3-2. Basic concepts associated with objects of threat outlined in the operational system are discussed as appropriate in the other chapters dealing with the related categories of such activities.

Antisocial Technologies

Antisocial technologies may be defined as the range of capabilities to render destruction or damage in a deliberate manner to a specific target or object(s). There literally are thousands of definitive techniques or instruments which can be applied in an antisocial manner. A comprehensive discussion of this entire set of technologies/techniques would require several volumes and is beyond the scope of this project. However, the techniques/technologies lend themselves to classifications for which the major highlights can be outlined. These highlights suffice to set the stage for a realistic underwater activities forecast.

- Explosives are being continuously developed and perfected. Small scale devices with nuclear capability are commonly expected. The general pattern is for more power to be packaged into smaller units. Smaller units than those in current use will have major destructive potential for a given vessel or offshore facility. This reduction of packaging size opens the ways in which such devices can be delivered. A small explosive device may be attached to or imbedded within marine mammals trained to "home-in" on certain types of targets. Camouflaged mines appearing to be natural forms of life, plants, or floating objects may be placed into well-charted ocean currents or movement patterns to be detonated either electronically or upon contact with the end object.

- Radiation may be employed in a variety of complex ways. It may be used to alter genetically the marine life forms, presenting direct threats to the marine agricultural activities. It may be emitted consistently at very low levels, hardly distinguishable from natural radiation, into populous fishing grounds, using the marine life as carriers of radiation into human diets, and hence threatening large population groups in almost nondetectable form.

These types of threats may promote fear into persons, making them unwilling to consume marine life and agricultural products. These threats conceptually are used largely as a means of either disrupting the marine agriculture or endangering human life.

- Chemical agents (such as various acids) may be used to act directly against property, against personnel involved in offshore operations and/or against marine plant and animal life. These chemical agents either may be used in a direct or indirect fashion. The most extreme concepts for the utilization of chemical agents suggest changing the chemical composition of the ocean to render the entire marine environment a hazard in specific localized areas.
- Biological agents and actions may be directed in many forms. The implanation of disease generating organisms can occur against either human or marine plant and animal life. Genetic developments offer potentials of new species or alteration of the generational genetic strains of marine life in ways to impair the integrity of the life form and its economic utility. Incompatible species which may be predators upon various forms of desirable marine animal and plant life can be introduced purposely as instruments of destruction.
- Abilities to modify and/or control natural forces are emerging in a number of areas. Climatic modification and limited control is one such area. Prospects of triggering earthquakes and other geophysical eruptions represent other areas.
- Behavioral control technologies whereby either human or other forms of animal life may be "programmed" to perform various actions up to and including personal sacrifice of life are a growing body of science and are now emerging into the arena of applied technologies.
- Forms of delivery systems expand and change rapidly as available instruments for transporting and techniques of destructive potential are developed. These include mechanical delivery systems such as remotely controlled submersibles, camouflaged and directionally controlled mines, marine mammals implanted with a destructive device who then carry the device to its point of application. The integration of mechanical and natural systems as a component of a delivery system is also conceivable. In this circumstance, as the patterns of ocean currents and movements become more fully known, it will be possible to utilize them into various mechanical devices as integral components of a single delivery process.

Preventive measures, detection techniques, and appropriate means of assessment and response are increasingly important and highly difficult yet necessary to confront the threats from nonmilitary aggression.

Natural Forces/Disasters

The natural forces which can present threats to underwater environment are of several types:

- Climatic forces, such as hurricanes, fog, temperature, and various other weather phenomena
- Geophysical forces, such as earthquakes, volcanic eruptions, the rise and fall of land masses, and other shifts in the earth's crust
- Oceanic forces, including tides, currents, waves, and various other physical movements of the marine environment
- Marine life, including dangerous species such as sharks, and predators on commercial marine life, and intrusion of undesired plant life

Major research efforts are being directed at intensifying the capability of predicting when, where, and at what force natural threats to property and life will arise. This predictive capability will entail a related requirement that such knowledge be employed to improve protection.

Beyond the concepts of prediction, lie concepts of humanly engineered modification and control of the occurrence of such natural phenomena. Stimulation of retardation of fog, hurricanes and other storms, of earthquakes, and of various geophysical shifts are coming into the realm of technological potentials which are now being defined and explored.

Accidents

Accidents are classified into those involving transportation and other vessel movements, and those involving other forms of functional activity. The basic concepts related to accidents include:

- Factors which will determine types, size, and nature of vessels and other hardware found in the marine environment
- Factors which will determine the number, traffic, or use patterns and timing of the use of such hardware and facilities
- The type of navigational, traffic, and movement controls plus the various other forms of required safety specifications and regulations

Discussion of these concepts appears within the relevant chapters dealing with the categories of activity to which they apply.

Unsafe Behavior

Unsafe behavior may stem from incompetence, ignorance, irresponsibility or negligence. Various courses of action are available with which to cope with the potential threats of unsafe behavior They include training and certification programs, traffic control, weather information and communications of unsafe conditions to all persons operating within the marine environment, and sanctions for law enforcement actions against persons acting irresponsibly.

Protection from unsafe behavior can be achieved partially by appropriate design of engineering equipment. Careful attention to equipment specifications makes for safer operation of marine related vessels and hardware. Buffer zones and other forms of geographical restrictions also are important instruments through which to deal with this set of problems.

Preventive Systems of Protection and Recovery

The most desirable means of protection is to preclude successfully the emergence of a threat in the first place. Concepts related to prevention include:

- Navigational systems and aids including electronic, visual, radio or sonic, radar controlled, buoys, satellite tracking stations, and various other forms of detection systems
- Movement control, including shipping lane designation, off-limits areas, restricted usage within certain areas or under certain conditions
- Zoning, i.e., the setting aside of various areas within the marine environment for certain uses, along with the prohibition of certain other uses
- Standards and regulations such as the development of operational specifications for personnel and equipment, and the backing of these specifications with appropriate legal penalties which will ensure their application
- Surveillance/prediction including the many forms of surveying the marine environment to determine both human and natural activities and activity patterns
- Enforcement credibility such as the perceived capability to enforce any and all regulatory or governmental rules and responsibilities, and the adherence to the law in behavioral patterns

Proactive Systems of Protection and Recovery

If threats cannot be prevented, then the most desirable means of protection is some form of proactive system which will neutralize a threat after it has materialized, or barring neutralization, will reduce the potential damage of that threat. Technological concepts related to this proactive interception include:

- Effective detection and assessment--the capability to know that a threat is pending and to evaluate its seriousness
- The capability to intercept the threat in a manner which either will neutralize it completely or will render its damage potential as small as possible
- Evacuation and removal including the capability to get potentially damagable personnel and resources out of the path of the threat if the other preventive and proactive methods have failed

Each of these actions entail specialized technological systems and concepts. Detection of aggressive threats from, for instance, implanted explosives being transported toward target areas is an entirely different concept than the prediction of dangerous weather conditions. Likewise, climatic prediction devices also are entirely different than those employed for the forecast of earthquakes or volcanic eruptions. The evacuation of personnel from undersea work habitats or from a surface rig into an undersea rescue shelter is an entirely different process than evacuation of personnel by helicopter.

Many of these specialized technological concepts are discussed in the preceding chapter on military activities and in subsequent chapters on the other sets of activities. In general, there will be substantial progress made across all of these technological fronts throughout the next twenty-five years and beyond. Many such developments will be made in connection with nonmarine and underwater activities. Others will be specially, and perhaps even exclusively, directed at the underwater activities themselves.

Reactive Systems of Protection and Recovery

Once the preventive or proactive systems have failed and the impending disaster has struck, the next line of action is reactive. This requires:

- Adequate surveillance to know where personnel and assets are and to locate each of them specifically enough to direct further rescue or repair efforts
- The launching and accomplishment of appropriate rescue actions

- The launching and accomplishment of appropriate neutralization actions, i.e., the actions needed to restore the damaged area to as near its predamage state as is feasible
- Salvage actions, including location, protection, and actual achievement of needed salvage operations

These systems are similar to the preventive and proactive concepts in that they too are specialized in terms of purpose, type of resource, and type of damage involved. As the underwater activities increase in scale and scope, there will be a dramatic and persistent demand for the continued technological upgrading of this entire family of protection concepts.

KEY DRIVING FORCES, KEY BARRIERS, AND OBVIATING FACTORS

The main driving forces, key barriers, and obviating factors, outlined in Figure 3-2, are discussed in the next section.

FIGURE 3-2: KEY DRIVING FORCES, KEY BARRIERS, AND OBVIATING FACTORS

KEY CONCEPTS	KEY DRIVING FORCES	KEY BARRIERS	OBVIATING FACTORS
Objects of Threat Discussed throughout all other categories as applicable Sources of Threat Antisocial Technologies • Explosives • Radiation • Chemical Agents/Actions • Biological Agents/Actions • Genetics • Control/Manipulation of Natural Forces • Behavioral Control • Delivery Systems Natural Forces/Disasters • Climatic • Geophysical • Oceanic Forces • Marine Life Accidents • Transportation Related • Economic Process Related Unsafe Behavior • Incompetence • Ignorance • Irresponsibility Systems of Protection and Recovery Preventive • Navigation • Movement Control • Zoning • Standards/Sanctions • Surveillance/Prediction • Enforcement Credibility Proactive • Detection/Assessment • Interception • Evacuation/Removal Reactive • Location/Surveillance • Rescue • Neutralization • Salvage	• Increasing density, complexity and diversity of offshore material and human resources • Developmental dynamics of antisocial technologies • Proliferation of antisocial technologies • Propensity for "aggression" • Growing predictive capabilities for natural forces • Technological dynamics of protective and response capabilities • Growing probability of at least some major aggressive terrorism somewhere against underwater resources • Probability of major disaster affecting marine resources with resultant demands for action	• Technological barriers to antisocial technologies • Technological barriers to protective technologies • Costs of protective capabilities • Inertial tendency to act in new areas of application until major events occur	• Antisocial technologies become "frozen" • Natural threats cease • Human behavior becomes fully "responsibile" • Offshore development regresses rather than progresses

THE TAILORED VIGNETTE

1. *The demand for more effective protection systems will grow steadily, becoming both more intense and more broadly based.* The primary sources for this increased demand for protection are:

- Developments in the density, complexity and diversity of offshore activities and human resources which are outlined in other chapters
- The expanding level of threat posed by nonmilitary aggression and antisocial technologies
- The increasing capabilities to predict natural phenomena and to act in proactive ways to reduce the threat or mitigate the damage
- The accelerating economic and technological potential of having more effective protecion systems

2. *In relative terms, these demands will emphasize greater attention to preventive and proactive protection. But there still will be a stringent expectation that the reactive capabilities of protection agencies and institutions will be retained at a capacity to handle reactive requirements which occur.* The principle basis for emphasis upon prevention stems from the fact that some of the threats such as those posed by antisocial technologies and from unsafe behavior will be very difficult to detect within sufficient time to take proactive action. In many cases, proactive actions will be preempted simply because there is no effective means of threat definition and neutralization.

The development of prevention measures will accelerate as the potential loss of property and life grow. Concurrently proactive protection measures will be stimulated.

3. *Advance in the state-of-the-art of antisocial technologies will continue across the entire spectrum of possibilities outlined in the section of this report on basic concepts.* Termination of this trend would require either of three basic conditions which we do not consider to be probable. These include:

- Fully effective international controls and agreements which prohibit the development of the antisocial technologies
- A loss of interest or incentive on the part of various nations and interest groups (including scientists and technologists) to having the antisocial technologies further developed

- A change in human behavior which would result in voluntary abstention from application of such potentials even though the technical feasibility exists

Some international controls will be negotiated on several devices of mass destruction which can be developed and delivered only through large scale, centralized organizations such as national governments and military departments. Examples are the present agreements related to chemical and biological warfare and the current negotiations related to the SALT talks. These agreements will necessitate complex systems of surveillance and control which are considered in Chapter 2 on military activities.

The extent to which such agreements are negotiated will be influenced by the forces of human nature and desires for power. It is likely that the intellectual resources will be redirected to pursue other antisocial technologies, thus intensifying the number and the rate at which such technologies are advanced.

4. *The essential monopolistic position over the development, production, and application of antisocial technologies which generally has been held by organizations and agencies of national governments will be eroded. Extended utilization of such capabilities will be operated by smaller organizations at lower costs and with more flexible forms of delivery.* At present most of the significant technological advances have been developed as leading states-of-the-art concepts. Therefore, the operation of these technologies has been captively retained within the relatively small community of technical personnel involved in their development. But as the application of these technologies expand throughout the nonscientific and scientific community, they will become more available to the general technical personnel.

The huge front-end developmental costs associated with such technological advances are not a restraint upon their ultimate development and production. This is a function of both the general dissemination of knowledge which can be readily available and of the changing sizes and means of production.

Finally, the elaborate delivery systems characterized by strategic bombers, submarines, and intercontinental missiles are giving way to many simpler, more clandestine types of delivery systems.

There appears to be no reason to anticipate a shift in the basic directions of the above trends. As they continue to emerge, the erosion of governmental monopoly over antisocial technology will accelerate.

5. *Although the desire to apply such technologies may not be in as latent a status as perceived today, the propensity for application of antisocial technologies will expand at least as far as its operational execution is concerned.* The motivational factors which undermine overall international interests to employ antisocial technologies are complex and only vaguely understood. Some of the more fundamental motivational drives were discussed under military activities (Chapter 2).

We cannot specify how these motivations are presently manifested, but there are some general factors and situations which clearly relate and define the degree to which such inclinations exist, and the probability to which those possessing the motivations will act upon them. Among these are such factors as:

- The growing intensity of international economic competition and the enlarging role of the marine environment as a component of the world economies
- The growing visibility of the have/have not gaps, and the rising militance of their world attitudes
- The fact that many future antisocial techniques if employed will make detection and affixing of responsibility extremely difficult if not impossible
- The general political climate and growth of terrorism, sabotage, and related political and economic "undergrounds;" this includes such emerging debates as state that the industrial age should be "rolled back" or that the advanced nations should redistribute their wealth or have it stripped from them
- The growing difficulties of practicing these propensities through legitimate governmental instruments including legitimate and open military hostilities
- The increasing vulnerability of complex operational systems to the effective application of antisocial technologies, i.e., the greater "payoff effects"

While this list is far from being exhaustive, it illustrates the range of factors involved. We judge that the underlying driving forces related to all of these factors will continue to operate to increase their presence and the related propensities which accompany that presence.

6. *Protection systems against nonmilitary aggression utilizing antisocial technologies will lag seriously behind the emergence of the potential destructive capabilities and the related threats which emanate from such potential.* The costs of defensive protection systems are significant. Many years of expensive research and development will be required to obtain such protective capabilities. It is not likely that these threats will be taken with sufficient seriousness to have the responsible agencies initiate the needed developmental activities in advance. Nonetheless, should such initiatives be launched, it also is unlikely that they will command sufficient budgetary priority to sustain the long term funding which would be necessary to develop protective measures to confront the threats as they emerge. The protective gap already exists and it will probably continue to widen.

7. *There will be a number of dramatic instances involving damages from nonmilitary aggression somewhere in the world. The probability is high that some of these instances will occur within U. S. waters, or within waters where U.S. interests are involved.* This forecast is simply based on a probability estimate that as the number of potential actors, potential means, and potential objects of such aggression increase, the likelihood of an aggressive application also increases. The limited nature of the destruction, and other factors surrounding such applications will result in some occurrences of aggression, etc.

8. *The effect of the above events will be to raise a public outcry for effective protective systems. One or more congressional investigations and various other publicly held inquiries into the matter will elicit to the public the degree of the "protection gap" and type of potential "threat". Responsible governmental officials including the Commandant of the Coast Guard will be "called upon to justify their lack of action" and to formulate quickly appropriate measures to be taken.* The history of public policy is replete with examples of these kind of developments. This history suggests that the nature and probability of future occurrences developing is a function of the conditions which stimulate them.

9. *There will emerge a series of major drives to develop effective protective systems. The combined trends of antisocial technological developments plus technologies of protection might be best characterized as a "threat/protection race." This will have its counterpart within the military activities and will become a new component of the overall arms race.* This capability will

be distinguishable in terms of protective systems because of the specialized nature of the technology and its application. The protective system will concentrate upon proactive capabilities and upon having quick reactive response capabilities. Problems of detection and identification will be extraordinarily difficult. The ability to discriminate between natural phenomena and deliberate acts of aggression will be impossible for some types of activity. For example, consider the problem of determining whether a mammal approaching a vessel is armed with a destructive device. Consider the problems of determining whether low levels of radiation are natural or deliberate, whether undesirable genetical changes are natural or designed, or whether the unintended results are from fully legal activities which have in some way disturbed the ecological systems.

Consider further the problem of determining responsibility for such actions. These and may other factors will make the overall challenge of developing proactive mechanisms great and will foster the development of proactive capabilities to deal with the incidents that preventive and proactive procedures were inadequate to handle.

10. *Although many improvements in protection will emerge, the "protection/threat gap" will not be fully closed. This will drive officials to seek improved forms of intelligence by which to know whether antisocial technological applications are being readied and by whom. This intelligence network will be similar to the type of knowledge obtained with respect to military operations and to criminal operations on the mainland.*

In essence, this shift toward intelligence systems will be an effort to move the protection system forward into the preventive phase. Maximum protection will emerge only if the potential behavior can be defined and preempted at the source or immediately after the "launch" of the antisocial technological operations.

11. *The development within the various fields of science and technology will evolve a slow but constant stream of improved capabilities to predict the threats arising from natural phenomena.* Many of the specifics associated with this forecast are discussed throughout the other chapters. In general, it can be said that these predictive powers will flow from:

- The rapidly growing understanding of the physical forces of the ecosphere, including underwater, surface, and above surface relationships
- The rapidly increasing instrumentation techniques and installed systems which make highly sophisticated and constant ecological monitoring possible
- The rapidly growing developments of processing and analytical techniques for dealing with heretofore unmanageable quantities and complexities of data

12. *Advances will be made in modification and control of natural phenomena, but they will not provide the capability to prevent threats from these natural events.* The possibility to predict, plus the growth of offshore resources to be threatened with these natural phenomena, will stimulate greater demands of modification and control technologies. Certain short range weather modification capabilities will most likely emerge. These will include the ability to disperse fog and storms under certain conditions. The ability to control the longer term characteristics of weather and climate are well beyond the horizons of this study, at least in terms of engineering application. Also beyond the scope of this forecast are the capabilities to modify earthquakes, major ocean currents and various other aspects of natural threats to marine resources.

13. *The predictive capabilities, plus the lack of capacity to have a fully effective preventive system to control threats from natural phenomena, will result in complementary demands to use the knowledge within a proactive framework. A system of adequate surveillance, rapid alert and appropriate evacuation or other "damage deterrent" procedures will be employed. Also employed will be engineering standards for equipment design, such that the capacity to withstand calculated levels of natural forces is a part of operational equipment.*

The mechanisms and concepts required to evolve this type of protective system are already in place. Basic differences will be in substances and detail rather than in terms of entirely new types of requirements. However, some novel approaches may be experimentally developed, such as having underwater habitats as shelters of refuge for workers in offshore facilities from storms and other dangers on the surface.

14. *The range and potential threat from accidents will grow in all categories as a direct result of increased activities. Major drives will be made to instill*

new regulatory controls to assure that accident prevention programs are designed and executed effectively. These will include improved employment of sea zoning, navigation, and operational quality of equipment and personnel. This forecast emerges from the fact that potential for accidents arises as the number of actors and types of activities increase and as their density and interrelationships become more complex.

15. *The threats of transportation accidents will be raised by the changing nature of some vessels. The equivalent of the super tanker likely will be developed for at least some other major raw materials.* These advances are discussed in the chapter on transportation and throughout the other chapters on the various forms of underwater activities.

16. *Threats from unsafe behavior also will escalate as the overall activities expand and the equipment becomes more complex. New approaches and/or adaptations to existing approaches of qualification standards, equipment standards, informed operators and enforced rules of the sea including the subsurface areas will be employed to a markedly greater degree than at present.*

17. *Specialized search and rescue reactive capabilities will be possible and will be demanded. Such capabilities will have to respond to the changing circumstances of peril including various forms of undersea habitats, vessels, and economic activities.* The particulars of these activities and events are discussed in other chapters.

18. *Salvage operations will become more important, and will require new forms of mechanisms and responsibilities for location of damaged resources under the surface, protection of such resources from theft or other threats, and actual capabilities to conduct successful salvage operations for the entire range of potential resource damage or loss.* The particular type of resources involved as objects of salvage are discussed as relevant within other chapters. Salvage technologies will include the ability to spot the damaged equipment, to guard it with both physical presence and remote control devices, and to raise large cargoes, vessels, pipelines and various other forms of equipment to the surface, transport them to repair or restoration, or scrap reclamation facilities.

The outlines of this tailored vignette, along with time-phased probability estimates and some details of operational hardware that will be employed are contained in Figure 3-3.

FIGURE 3-3: TAILORED VIGNETTE - PROTECTION OF PROPERTY AND LIFE

FORECASTED DEVELOPMENTS	PROBABILITY/TIMING 1981-85	1986-92	1993-2000
DEMAND FOR MORE EFFECTIVE PROTECTION SYSTEMS GROWS MORE INTENSE AND BROADLY BASED	GOOD	HIGH	HIGH
ANTISOCIAL TECHNOLOGIES BECOME DEFINED AS MAJOR UNDERWATER THREATS (CIVILIAN)			
• EXPLOSIVES	HIGH	HIGH	HIGH
• RADIATION	MINIMAL	LOW	GOOD
• CHEMICAL AGENTS/ACTIONS	LOW	GOOD	HIGH
• BIOLOGICAL AGENTS/ACTIONS	MINIMAL	LOW	GOOD
• GENETICS	MINIMAL	MINIMAL	LOW
• CONTROL/MANIPULATION NATURAL FORCES	MINIMAL	MINIMAL	LOW
• BEHAVIORAL CONTROLS - ANIMALS AND HUMANS	GOOD	GOOD	GOOD
• DELIVERY SYSTEMS:			
MANNED	HIGH	HIGH	HIGH
REMOTELY CONTROLLED	HIGH	HIGH	HIGH
COMBINED WITH NATURAL FORCES	LOW	GOOD	HIGH
SERIES EVENTS SOMEWHERE, ENTAILING APPLICATION OF ANTISOCIAL TECHNOLOGIES UNDERWATER	GOOD	HIGH	HIGH
WIDE CONCERN DEFINES "PROTECTION GAP," SEARCHES FOR "SCAPEGOAT" GOVERNMENTAL AND INITIATIVES	GOOD	HIGH	HIGH
RACE TO CLOSE "PROTECTION GAP" BEGUN AND SUSTAINED, INCLUDING DESIGNATION OF AGENCY FOR CIVIL PROTECTION MANAGER	GOOD	HIGH	HIGH
GROWING REQUIREMENTS RELATED TO PROTECTION FROM NATURAL PHEONMENON/CATASTROPHES			
• ABILITIES TO PREDICT MORE SPECIFIC EVENTS AND ASSESS THREAT	HIGH	HIGH	HIGH
• ABILITIES TO MODIFY THE NATURAL FORCES TO AVERT THREAT: CLIMATIC	LOW	GOOD	HIGH
GEOLOGICAL	MINIMAL	MINIMAL	MINIMAL
THREATS FROM ACCIDENTS CONSTANTLY RISING, LARGER RISKS, MORE COMPLEX, MORE DIVERSE:			
• A MAJOR "BLOW-UP" OF AN LNG OR SIMILAR CHEMICAL CARGO CREATES CONCERN FOR PROPETY PROTECTION	LOW	HIGH	HIGH
• SUPER ORE SHIPS AND OTHER VESSEL INNOVATIONS	MINIMAL	LOW	GOOD
• DENSITY TRAFFIC AND MULTIPLE USES IS MAJOR CONCERN IN SOME LOCALES	GOOD	HIGH	HIGH
• UNDERWATER HABITATS, VESSELS, EQUIPMENT BECOME DEFINED THREAT AREA	HIGH	HIGH	HIGH

CHAPTER 4: ENERGY ACTIVITIES

DEFINITION

Underwater activities associated with energy emerge from the following basic relationships:

- Traditional energy fuel deposits are located beneath the earth's crust; a significant share beneath the water.
- Natural forces within the marine environment can be captured and converted into forms of energy vital for increasing consumption.
- The offshore environment frequently is viewed as a place to locate energy production facilities such as nuclear plants or large-scale solar collection areas.

Activities related to extraction of traditional fossil fuels and other mineral fuel sources are more properly considered as part of marine mining activities. As will be seen, the extraction of fossil fuels from the seas will be the most significant component of marine mining. Despite this fact, these energy fuel mining operations are considered for purposes of this analysis as components of the energy activities. Other aspects of minerals mining operations are discussed in the next chapter.

The underwater energy-related activities and systems are more specifically classified as shown in Figure 4-1.

FIGURE 4-1: ENERGY SYSTEMS RELATED TO UNDERWATER ACTIVITIES

BASIC CLASSIFICATION	SPECIFIC ENERGY SYSTEM
Fossil Fuel Energy	Offshore production oil and natural gas Offshore production coal
Mineral Energy	Offshore production uranium
Solar/Wind Energy	Floating collection of solar heat Floating windmills Ocean Thermal Energy Converstion (OTEC)
Biomass	Kelp and other aquatic vegetation
Natural Marine Forces	Tidal power Ocean currents Wave energy Deep sea pressure power Ocean hydroelectric power Water Salination power
Natural Geological Forces	Underwater geothermal energy
Marine Energy Plant Siting	Floating nuclear power plants Floating natural gas power plants Other floating or submerged power plants, refineries, or conversion centers. Floating industrial process plants located for direct consumption of ocean-generated energy.

BACKGROUND

It is generally proclaimed that the world is entering a new energy epoch as historically profound as the transition from dependence on animal energy to dependence on energy derived from fossil fuels. While it is still too early to say unequivically that the fossil fuels era is ended, it is clear that future energy strategies must derive alternative sources. Since this transition will not be either speedy or simple, we can expect that for the next twenty-five or so years the overall world energy picture will be a mosaic of at least the following basic patterns:

- Continued growth in absolute demand levels for all fossil fuels, with an increasing priority given to coal as the most plentiful of such sources.
- A growing awareness of the finite nature of fossil-based energy and a search for more deposits.
- Continued development and proliferation of nuclear energy, especially nuclear power plants for generation of electricity.
- A rapidly growing capability to employ solar energy and other natural forces such as hydropower and winds.
- An increasing priority given to the pursuit of renewable sources of energy which can be converted to forms such as electricity for general purpose application and use.
- An increasing search for an alternative to petroleum as the basic fuel for transportation.

In viewing probable future developments in energy, it is especially important to note that the projected demand patterns which would accompany continued world economic development are such that substitute sources will not displace nor replace traditional sources immediately. Rather, they will fill an otherwise nonfillable gap between supply and demand. This reality makes the economic, political, and social dynamics of alternative energy technologies a more potent and far less rigid vested interest. For example, the oil companies need not be overly concerned with the potential of a substitute fuel for gasoline. They might lead the development of such an alternative in order to have continued employment of their basic capital/delivery systems. It is precisely this atmosphere which makes the feasibility for innovation somewhat more positive.

Where major institutional and sociological innovations are required, the process is never quick or easy. The matter is introduced only to place

the forecast of energy and underwater activities into an historic perspective critical to a reasonable insight into the future developments within that sphere. The potential importance of marine-based energy systems is underlined by current estimates showing that natural energy sources over and in the oceans are sufficient to supply many times the projected world demand. The problem is to harness such energy, convert it into useable form, and get it where needed.

FUNCTIONAL SYSTEM

The present and future components of the functional system for energy related underwater activities represent a complicated network of subsystems which can be described briefly as follows (see Figure 4-2):

End Use Consumption Systems/Demands

Marine-based and other energy systems are shaped ultimately by the degree and nature of overall energy requirements and the various systems whereby the basic energy sources are converted to useable form at the points of final consumption. All of these factors enter into this set of subcomponents.

Basic Offshore Energy Sources

The nature of underwater energy related activities is affected primarily by the type of basic energy sources located within the marine environment which entail operations on or below the surface. As was noted in the earlier discussion, the marine environment contains a vast array of potential energy sources.

Discovery Systems

The underwater related energy sources must not be only demanded, needed and/or available, they must be known or be perceived to exist in a form which is technically feasible for exploitation. Discovery techniques and systems are the processes through which this perception occurs. The range of discovery procedures which are given significant attention are in turn heavily related to the types of energy demand and the types of energy conversion technologies.

Extraction Systems or Acquiring Mechanisms

The offshore energy sources must be extracted or acquired from the underwater or marine environment in order for them to be employed in consumption systems. Here we address offshore oil and gas wells, coal mines, solar collection

systems, or the various other mechanisms involved in obtaining the basic energy source for consuming systems.

Transportation Systems

Basic energy sources must be transported either to an intermediate processing facility such as a refinery, or into related distribution systems which get fuels or energy sources to their next point within energy systems.

Refining and/or Conversion Systems

Energy sources almost universally require some form of intermediate processing or conversion system to modify or transform them into the form needed for final use. These include petroleum refineries, electrical generating plants, and various other energy conversion technologies.

FIGURE 4-2: FUNCTIONAL SYSTEM: ENERGY

End Use Consumption Systems/ Demands ↔ Refining and Conversion Systems ↔ Energy Transportation Systems ↔ Extraction or Acquiring Systems ↔ Discovery Systems ↔ Basic Offshore Energy Sources

GEOPHYSICAL PERSPECTIVES

The energy related activities cannot be viewed collectively when considering various geophysical perspectives. Each set of activities has requirements which may or may not appear in other sets. A brief summation of the principal requirements associated with each energy area is provided below. A map with potential energy sites concludes the chapter on page 4-37.

Deposits of oil and gas generally are located along coastal margins (within the continental shelf area) below the seabed in sedimentary basins. Once located, drilling rigs can operate in varying water depths; most structures are found in depths of 600 feet or less, although oil is currently extracted at depths of up

to 3500 feet off the coast of Thailand. It is desirable to site rigs at a distance from frequently traveled ocean lanes, recreation sites, and coastal population centers, and within reasonably calm waters not subject to harsh environmental irregularities.

Within U.S. waters, offshore oil and gas production systems are prevalent in the Gulf of Mexico. There are some structures off the Pacific Coast as well. Both Atlantic and Alaskan coast offshore areas are presently being surveyed and explored to determine extraction feasibility.

Coal from underneath the seabed is extracted via land-based shafts or from artificial islands. The material has been obtained from systems such as these in Canada, the United Kingdom, Japan, and Taiwan. Areas in the U.S. where offshore deposits are located and which conceivably could be tapped from land-based shafts or from artificial islands include the Gulf of Mexico, the Atlantic Coastal Region, Offshore Alaska (the Bering Sea), and the Great Lakes.

Production systems for uranium could take place along any of the coastal margins of the U.S., although the most attractive areas would be where seawater or seabed uranium mineral content is high. Few studies to date have been undertaken to determine comparative mineral contents by geographical locale.

Offshore collection of solar heat could take place along most coastal margins, although mid-latitudes generally offer the greatest sunlight. Assuming placement of collectors on fixed pile platforms, depth limitations would restrict siting; floating platforms would not be inhibited by depth restrictions.

Large-scale offshore wind energy conversion systems require relatively constant wind speeds of 25-30 mph with an estimated cut-off speed of 15 mph. Other proposed systems smaller in scale and generating capability require winds of at least 7 mph. Considering the number of offshore windmills required to generate electricity for large populations, scores, if not hundreds of floating or fixed pile structures would be needed. This would further limit siting to a distance from frequently traveled ocean lanes and recreation areas.

Most coastal margins of the U.S. could harness wind energy, although in order to generate sufficient energy to power large population centers, only a few U.S. coastal areas would be suitable. Wind speeds off eastern Florida are fairly constant and offer a relatively high velocity. On the international

front, technical studies have concluded that placement of windmills in the North Sea could provide the U.K. with a sufficient amount of energy for internal needs. Antarctic winds are strong and constant enough to be harnessed and the generated energy distributed to selected population centers.

In order to harness energy from ocean thermal gradients, temperature differentials of about 34-44^{o} are needed. Gradients such as these are common in equatorial waters. Within U.S. territorial waters, the Gulf Coast and the lower eastern coast of Florida have been judged as the most suitable locations for exploitation. Assuming present design features of OTEC harnessing structures, siting would need to be away from ocean lane traffic and distant from traditional recreation sites.

Kelp bioconversion is found primarily in the warm waters off the West Coast, from Mexico to Alaska. On the international front, kelp is located off the west coast of South America, in waters off the USSR's eastern borders, along the east side of New Zeland, in the Atlantic from southern Greenland to Nova Scotia, and in many other areas of the world too numerous to cite here. The bioconversion of other marine plants on the East Coast is conceivable.

Tidal power conversion usually requires a tidal depth of 25 feet or more to generate a significant amount of electricity. Two nations currently employ tidal stations: France's northwest coast at the Rance River, and the USSR's Kislaya Bay station. Potential sites in the U.S. meeting the above depth requirements for tidal conversion process include Baja, California, the Alaskan Cook Inlet, and the Passamaquoddy Bay off Maine. Outside of U.S. waters, the Canadian Bay of Fundy offers a frequently discussed potential site for tidal conversion. Many other areas of the world appear attractive: British river estuaries facing the Irish Sea, the Kimberly Coast of NW Australia, and much of the eastern coastal area of South America.

Harnessing ocean currents to generate electricity requires currents with a relatively high speed, i.e. the world's primary currents. The principal western boundary currents are the fastest oceanic nontidal currents, and of these, the Florida Current has the greatest speed/velocity because water is channeled in straits between Florida and the Bahamas. Studies have indicated that the total energy motion of this current is capable of producing about 25,000 mw of electrical power.

Wave energy conversion can be accomplished with practically any size wave. The amount of power which can be generated, however, depends in part on wave length and height. A wave height of less than two feet and length of 60 feet can generate .9kw of power; a wave height of about 9 feet and length of 175 feet can generate nearly 31 kw of power. It has been determined that maximum power levels can be generated at midlatitudes and longitudes towards the eastern end of the Atlantic and Pacific Ocean basins. The United Kingdom's and Japan's offshore areas have been assessed as excellent locations for wave energy conversion. Japan already employs wave-powered buoys.

Deepsea pressure power can be obtained only from deep sea ocean trenches of at least 10,000 feet or more. Two examples of where these deep ocean bottoms exist are the Pacific Kuril and Philippine trenches.

Wherever rivers enter ocean bodies, salinity gradients conceivably could supply differentials sizeable enough to generate power. A commonly discussed area in the U.S. which could utilize this system is the Mississippi Delta Region.

Any body of water surrounded by land on three sides represents a conceivable area for ocean hydroelectric power Within the U.S., both the Gulf of Mexico and Baja, California serve as examples. Closing these bodies to harness power, considered by many an engineering feat of impossible proportions, would obviate the flow of vessel traffic as freely as it traditionally moves in and out of these bodies.

Ocean geothermal energy is found in seabed tectonic plate areas, in close proximity of active island volcanoes, or within "submarine" volcanoes. The tectonic plate area in the U.S. waters extends from the Gulf of California to Washington State; the Hawaiian Island area offers another potential place where geothermal energy could be harnessed. However, the potential for land geothermal sites is much more promising than water-based locations.

Floating Energy Plants can be located along any coastal margins of the U.S. A nuclear power plant off the New Jersey Coast has already been planned, although regulatory and jurisdictional issues remain unresolved. Siting of a nuclear power plant offshore demands that it be distant from water areas subject to harsh environmental irregularities, e.g. hurricane regions, fault lines, etc., and that the plant be distant from ocean lane traffic, recreation sites, and large population centers.

TAILORED FORECASTS

BASIC CONCEPTS

The basic concepts are briefly outlined below and in Figure 4-3. They are discussed in further detail in the tailored vignette which concludes this chapter.

End Use Consumption/Demand Systems

Degree of Societal Energy Intensity

The pervasive manner in which energy affects virtually all dimensions of the society and individual life has been dramatized by current energy problems. This has served to catalyze a variety of philosophic debates concerning the overall "morality" and "ethics" of an industrialized economy/society extremely consumptive of basic nonrenewable resources. These debates are not new, nor are they confined solely to energy. But the energy issues have served to add a good deal of stimulus to them, and to bring forth active advocates with a variety of viewpoints. The ultimate philosophies which emerge victorious will greatly shape the future of not only energy, but of all other activities associated with this analysis. For present purposes, these basic issues can be defined by one of the following basic concepts:

- Limited Industrialization: Some analysts contend that as the age of fossil fuels comes to a close, the economic and social structures built upon the fossil fuels will no longer be sustainable. Such advocates contend that we should now begin to revert toward a less industrialized economy, characterized by lower energy use and energy uses of a more infinite type such as "human and animal muscle power." These same concepts are applied to other nonrenewable resources.
- Affluent vs. Basic Energy Society: A less extreme position than that defined above, this contention is that the economy should at least revert from energy affluence to basic energy characterized by:
    - Minimum reliance and use of individual transportation vehicles (except bicycles or motorbikes) and highway transport, replaced by maximum reliance upon mass transit and rail/waterway transport systems. The individual automobiles and cargo trucks now operating are relatively low in terms of energy efficiency per passenger or ton mile.

- Less energy intensive pleasure activities, which would eliminate a good deal of pleasure driving, motorized boating, etc.
- Restriction of indoor comfort control systems, i.e., limited use of air conditioning and lowered temperatures for winter heating.
- Restricted use of energy-consuming luxuries such as automatic appliances and electrical devices.
- Reduction or restriction of some industrial operations which consume large amounts of energy and are involved in production of "nonessential" goods.

- Alternate Environmental Design: A reorientation of land use and building design concepts which would permit drastically reduced demands for energy, including:
  - Concepts of very dense high-rise living patterns which permit maximum use of mass transportation systems, coupled with location of employment and service facilities to allow maximum return to the "walk to it" economy.
  - Concepts of alternate building design which greatly reduce demands upon energy systems external to the building itself. This is a combination of conservation techniques to reduce demand (such as insulation or differing window design) and solar collectors for on-site energy generation from natural energy forces.

- Transition to a New Post Fossil Fuels Era: The viewpoint that there is really no energy problem; rather the problem is one of technology and institutionalization. This view holds that energy problems are simply the result of an ending historic epoch termed the "fossil fuels era." This era will and should be replaced as rapidly as possible, not by a reduction of energy intense life styles, but rather by new energy sources and systems. These new energy sources and systems will employ nonfossil fuels and various renewable sources, including natural forces such as solar heat, wind, and ocean currents, temperature gradients within water environments, etc.

Transportation Systems

Transportation is one of the most energy-prolific functions. The transportation sector includes all forms of land and sea transport. While transportation vehicles and vessels employ many forms of energy, the predominant form of energy currently is that supplied by an internal combustion engine, usually fueled with some derivative of petroleum.

A variety of technological alternatives to conventionally powered vehicles and vessels is emerging. Nuclear power ultimately harnessed for small engines is one such possibility. Alcohol derived from biomass and/or garbage is another. Wave-powered vessels represent still another possibility frequently discussed. Battery powered engines, perhaps some composed of solar cells, show promise over the long run.

Other transportation considerations include the relative differences in the energy efficiency of contrasting modes of transport. Water transport is the most energy efficient, followed by rail transport. Highway transport is the least efficient. Large vehicles/vessels are generally more energy efficient than small ones where cargo transport is concerned. Personal cars and boats offer an inverse situation; larger individual cars or boats are less energy efficient than smaller counterparts.

There are those who contend that the basic level of energy demand can be and should be reduced drastically through substitution of an effective inter-modal network of transportation which permits people and material to travel over the most energy efficient mode/network. Mass transit, rejuvination of the rails, and supercargo vessels are illustrations of these concepts.

Still other concepts suggest that a good deal of transportation is for the purpose of communication, and that new communication technologies offer a major form of technological substitution for some transportation.

Commercial/Residential Building Systems

Buildings are also a major consumer of energy for functions such as heating, cooling, refrigeration, lighting, cooking, hot water, and powering many household applicances and tools.

The major forms of energy currently used by buildings are electricity, natural gas, fuel oil, and coal. Many studies show that a notable amount of a building's energy supplies could be provided from on-site solar conversion. Technology already exists for use of solar heat for heating and cooling. Longer range technological possibilities include efficient solar cells which would permit direct on-site conversion into electricity, the energy most used in buildings.

The adaptation of buildings for utilization of other energy substitutes such as coal is feasible, though expensive.

Industrial Processing

Huge amounts of high and low intensity energy are required to operate the industrial machinery of the U.S. economy and of all advanced economies. The most common source currently used for industrial processing are natural gas, coal, fuel oil, electricity and in some instances water and wind power.

Current concepts for future industrial energy include reversion to coal as a primary fuel rather than natural gas, fuel oil and other petroleum based energy. Other concepts include locational integration, i.e., an industrial plant requiring large amounts of heat for steam might be located close to a nuclear plant which expels heat. There are few concepts in the current spotlight, or which we can envision, that would shift fundamentally the fact that advanced industrial economies require energy intensive industrial processes.

Industrial Feedstocks

An entirely different relationship between industrial uses and energy sources exists in the area of feedstocks. Industrial feedstocks are industrial requirements for energy source materials, not as a source of energy, but as an alternative use as a raw material. An example is plastics derived from a petroleum base. Another example is the use of petroleum as a substrate to grow microorganisms which in turn serve as a source of high-quality protein for incorporation into foods.

The use of these basic nonrenewable resources to generate energy is probably the least economically valuable use which they can serve. Future technology probably will entail many different and higher value uses of petroleum, coal, and the entire range of nonrenewable energy sources.

These developments are not likely to exert major quantitative demands upon the world supplies of these resources until well into the next century. Thus, the basic demand from industrial processes will lean heavily in favor of fossil fuels rather than fossil-based raw materials.

Conversion Systems

The many conversion systems involved in energy are directly related to the sources and uses of the energy. For purposes of this analysis, the following basic conversion system/concepts will suffice:

- Internal combustion engines: used extensively in transportation systems but also in many other areas of economic and social activity. These engines essentially convert a fuel source into needed driving power via combustion. Traditional fuels are petroleum-based in some appropriately refined form. Current concepts are extending this range of fuels to include alcohol and other liquids or solids derived from renewable resources and/or garbage and waste streams
- Electricity: perceived by many to be the ideal system because it delivers a steady and constant form of power which can be used for an almost universal power or energy supply, and which can be derived from a wide variety of fuels and energy sources. These sources include combustible fuels such as coal, natural gas and petroleum, and hydropower, temperature gradations of the ocean, nuclear power, solar heat, wind and many others. Electricity is also easily transported into all areas and regions of the nation through national grids. Thus, there are those who advocate an "electrified nation;" one which places maximum reliance upon electricity as a universal form of energy for direct consumption. Electrical generating plants may be located on land or offshore. Some advocates of electrification view extensive offshore siting of electrical generating facilities both in terms of using marine energy sources and as safer or more remote sites for nuclear plants.
- Heating and cooling systems: techniques to convert fuels or energy sources into heat or cold which in turn satisfies some energy need. Heat generation includes production of electricity, industrial steam and intensive temperatures required for conversion of raw materials in such processes as steel making. Heat may also be the end product desired, such as warmth in buildings and homes. Cold generation may be needed for industrial processing of materials requiring cold, it may be used in refrigeration or preservation for both industrial and home uses. It may be used as a direct comfort generator such as air conditioning in buildings. Various heating and cooling systems are employed, using some form of fuel or other energy source.

- Other forms of conversion for power/drive: such as sails to capture wind to drive vessels, waves to generate motion converted to drive shafts and many other means of mechanical conversion.

It is clear that the underwater energy related activities will be largely determined by the ultimate decisions about the society's levels of energy intensity and the nature of end-use and conversion systems which are employed. These concepts in turn are directly affected by the availability of energy and by the state of technological capability to convert such energy to the needed form.

Energy Transportation Systems

The transportation of energy occurs in several ways. Some basic energy sources such as petroleum must be transported in bulk form to intermediate process points such as refineries and retransported to the points of ultimate use. Other fuels such as natural gas or coal may be transported into either intermediate processing points or into the final consumption points.

There are a variety of basic transportation concepts which relate to underwater energy activities. These include:

- Vessels of varying sizes and types to transport petroleum, natural gas or coal mined offshore into shore based facilities.
  - Super large vessels such as super tankers or ore carriers which would be appropriate for coal
  - Traditional tankers and cargo vessels
  - Underwater vessels such as submarine tankers and cargo carriers of varying sizes
- Pipelines for transportation of liquids or slurries carrying suspended solids.
- Transmission lines for transportation of offshore generated electricity.

Extraction/Capturing Systems

Basic energy sources (discussed below) must be either extracted from the earth and/or collected or captured from the natural force flows such as

solar heat or wind. These extraction/capturing devices related to underwater energy activities are:

- Surface based mining rigs
- Submerged mining rigs
- Bottom based mining rigs
- Offshore solar collectors
- Offshore wind collectors
- Extraction of chemicals/minerals suspended in ocean water.

Discovery Systems to Define Offshore Energy Potentials

- Observation
- Association of geological characteristics with the probability of underground resources/reserves, followed by "hit or miss" drilling operations in test sites
- Instrumentation which combines sonic, seismic, temperature and various other readings to discern the probable presence of reserves, estimate their dimension, and pinpoint their exact location.

Basic Energy Sources

Most of the same concepts are involved in underwater energy source activities as in land-based energy source activities. They include the types of energy listed in the specific inventory of underwater activities catalogued in the definitional section at the beginning of this chapter.

KEY DRIVING FORCES, KEY BARRIERS, AND OBVIATING FACTORS

The key driving forces, key barriers and obviating factors of relevance in forecasting underwater energy related activities are outlined in Figure 4-3, and are discussed in the following tailored vignette.

FIGURE 4-3: TAILORED FORECAST FRAMEWORK: ENERGY

KEY BASIC CONCEPTS	KEY DRIVING FORCES	KEY BARRIERS	OBVIATING FACTORS
End Use Consumption Demand/Systems Degree of Societal Energy Intensity Transportation Systems Commercial/Residential Building Systems Industrial Processing Industrial Feedstocks **Conversion Systems** Internal Combustion Engines Electricity Heating and Cooling Systems Other Forms of Conversion to Power/Drive **Energy Transportation** Vessels Pipelines Transmission Lines **Extraction/Capturing Systems** **Discovery Systems** **Basic Offshore Energy Sources** Oil and Natural Gas Coal Uranium Solar Heat and Wind Ocean Thermal Conversion Kelp and Other Aquatic Vegetation Tidal Power Ocean Currents Wave Energy Deep Sea Pressure Power Water Salination Power Ocean Hydroelectricity Underwater Geothermal Energy	• Man's basic desire for affluence and the institutionalization of the growth value system • The growing technological opportunity for energy alternatives plus the clear feasibility of some offshore alternative • The present technological/economic opportunity for continued energy intensity • The increasing costs of land based energy which makes economically feasible other alternatives • The scarcity of traditional energy from land based resources • The fear of nuclear plants in relation to populated and/or land areas • Need for greater national supply independence • Problems of foreign exchange and energy importation	• Advocates who fear that continuation of the industrial age and extrapolated growth will lead to world disaster • Comparative economic costs and difficulties of offshore development • Environmental risks • Conflicting uses of offshore areas/zones • Aesthetic preservation • Geophysical requirements • Technological developments which are needed	• Decision to move toward de-industrialized society and non-energy intensive society/economy • Substitute consuming systems which obviate demand • Suitable substitutes from land based sources at more favorable costs

THE TAILORED VIGNETTE

It is clear from the preceding discussion that some of the marine-based energy activities are unique to the marine environment. Concepts for harnessing tidal power and ocean currents illustrate this point. Other marine energy activities are extensions of land-based energy systems, e.g., offshore petroleum, natural gas, and floating nuclear power plants.

In general, energy activities within the marine environment are linked specifically to energy consumption needs and patterns on land. If marine-based energy activities were related only to marine-based energy uses, future developments would be entirely different than if these activities were undertaken to support land-based consumption. It should be kept in mind that the marine/underwater environment will not be employed as a center for energy activities related to land-based consumption unless such systems offer some advantage over competitive land-based alternatives, or unless the land-based alternatives are insufficient to supply total needs.

As we approach our forecasts of future underwater activities associated with energy, we must evaluate constantly the following relationships:

- How do land-based end use consumption systems relate to the energy sources derivable from the marine/underwater environment?
- How do marine-based or offshore consumption systems relate to the energy sources available in the marine environment versus those available from land? For example, it is possible to operate a ship with fuel extracted from a land-based oil well, or the lights on a marine platform from electricity generated in a power plant on shore.
- How do land-based and marine-based energy sources relate to one another in terms of their ability to fill the absolute supply/volume requirements, the comparative availability, and the comparative economic feasibility.

All of the above relationships are shaped directly and significantly by the available technology developed over the forecast period.

The basic choice between continuing energy-intense economic growth and social development or energy regression or arrestment will be made in favor of continuing energy intensity. Thus, the overall demand for energy will continue to escalate at a rate within one to three percentage points of that established over the last several years. We believe that the ultimate

resolution of these debates will be in favor of continuing energy intensity and related increased energy demand, given:

- The current level of energy intensity and the overall dependence of current standards of living upon such energy
- There are at lease several decades of current energy sources/supplies yet available within the world's resources
- The basic human nature to resist regression of economic standards of living
- The entrenched constituencies and institutional inertia which resist the painful effects of adjustment toward a less energy intense society
- The increasing technological conceptualization that alternatives are possible, and;
- The price of deindustrialization is simply too high.

To believe that all or even most of these forces could be reversed within the next 20-25 years seems quite far-fetched.

During the next twenty-five years, we will witness an era of transition toward reliance upon different forms of energy systems. The transition will not be complete, and most consumption will remain linked to types of energy currently in use. However, because the necessity of the transition will continue to become clearer, technological creativity will be stimulated further and the development of alternative energy concepts now underway will continue and expand. This forecast flows from a combination of the above statements forecasting continuing affluent energy intensive living, and the continuing evidence that the non-renewable energy resources are becoming more scarce. Transition will begin, but transitions involving such pervasive and complex relationships in advanced societies are neither speedy nor simple. We expect the old and the new energy eras to run in parallel for several decades.

The search for alternative energy sources and systems will continue to grow more intense as the need for greater national energy independence increases along with the realization that such independence is not achievable through contemporary fossil-based energy sources. The need for greater energy independence is related to both world economic and national security imperatives. Many trends show that the U.S. is becoming an economy which is increasingly resource dependent, i.e., more and more basic raw material imports are sought. Petroleum is currently the most visible of these resources, but in actuality it is only

one of a quickly expanding list of similar import requirements. At the same time, the world is moving into a new era of international competition. A larger number of advanced economies are competing for world markets and a large portion of these advanced economies are themselves resource dependent. Thus, there is likely to be growing competition in finished goods markets and for raw material supplies on a world-wide basis. The U.S. is beginning to experience the antecedents of this new era with the seemingly painful discovery of chronic and growing balance of trade deficits. The future economic well-being of the nation will depend upon the ability to retain at least a reasonable national balance in international exchange. Alternative energy sources will be pursued as a major means of reducing the nation's requirements for importation. Concurrently, it will be beneficial for the U.S. to emerge as a technological leader in some alternative energy systems in order to create a potentially useful export to other nations.

From a different perspective, greater independence also will be sought as a means of reducing the dependency and vulnerability of the U.S. economy and the national security system.

Technological developments will be sought across a broader spectrum of possibilities in the climate discussed above than would otherwise be the case. Not all of these exploratory developmental efforts will prove fruitful. But we do believe that many marine-based alternatives will be more seriously explored at least from an experimental vein because of the overall national importance of greater independence. National self-sufficiency also will be complementary to a variety of other issues which will make marine-based energy alternatives preferable to land-based alternatives.

Systematic discovery and inventory of the Earth's total resources and ecosystems will continue to evolve at a rapid pace. This will lead, toward the end of the century, to more precise models of energy reserves, energy generating forces and potentials, rates of depletion, and the overall ecological consequences to tapping these sources. The following trends and developments working concomitantly will make technologies for discovery more accurate and credible, and will permit them to be employed for many purposes and motivations.

- The growing demand for offshore resources such as minerals
- The overall scientific investigations directed at more complete and accurate geological and atmospheric inventories

- Further research in life systems of the ecosphere
- A rapidly developing means of instrumentation
- The institutionalization of both general purpose and special purpose "searches"

As the above developments emerge, the large reserves of all fossil fuels will become known. Also, there will be accurate plottings of the energy potential which can be captured from ocean forces.

Utilization of offshore electrical generating plants will become a major area of interest; a number of these facilities will be constructed. They will include facilities for nuclear power generation, and possibly for offshore fuel burning generation plants (especially offshore coal), ocean gradient generation, ocean currents and perhaps even tidal power and wave power generators.

It is already clear that when the lag time for construction of power plants is considered, the U.S. will experience a series of critical electrical shortages during the mid 1980's. There are indications that the emergence and greater use of a nation-wide grid for national allocation and distribution of electrical energy will continue. This will make it possible to export electricity from one region to another, including that originating from offshore production. Thus, the reliance upon electricity as a highly flexible, general purpose energy (in terms of end-use systems) will grow. So too will the capability to distribute such energy within a national system expand.

In this environment, a high priority national search will be initiated to determine how "the electricity gap" can be narrowed. The nuclear "solution" will emerge as particularly appealing for an emergency measure. Yet, societal fears of nuclear plant operation in land-based population centers will not be eradicated. A compromise resolution will be viewed by some persons to include the development of offshore nuclear sites. The feasibility of doing this will be given an additional thrust by the emergence of a national electrical grid, and by the arrival of cable technology making transmission from sea to shore more efficient.

The offshore drive will not be limited to nuclear plants. In close association with nuclear exploitation, opportunities for harnessing marine forces and extracting other energy sources to produce electricity will be sought. Thus, experimentation will extend to such other ideas as offshore burning of

coal produced from underwater mines (a take-off from the offshore petroleum refinery concept), ocean gradient production, ocean currents, etc. It is conceivable that a multipurpose conversion plant might emerge which could employ any and all of the forces within its proximity, thereby greatly enhancing the stability and efficiency of the overall function.

More details on the operational aspects of this development are discussed under the following headings dealing with each of the activity areas.

Oil and Natural Gas

Suitable substitutes for use of oil and natural gas as fuels are technically feasible, and will be developed. However, they will not be developed to a sufficient scale to preclude dramatic growth in demand for oil and natural gas as basic components of our energy picture. While the demand may decline proportionately, it will still grow significantly in absolute terms, (the measure of significance to this analysis)

Even if major substitutes for gasoline and fuel driven engines for transportation were in hand and under production now, it would not be possible for alternate supply systems to grow at a rate sufficient to eliminate growth in the absolute demand for petroleum. The rising rate of transportation and increasing world economic development will advance demand more rapidly than these substitutes can become widely diffused systems. The vested interests ensconced in current petroleum systems such as gasoline distribution and related vehicular production would mitigate against a rapid dissolution of these investments and employment streams.

Substitution of coal, solar energy and various other alternate sources for production of electricity, industrial processing, and heating and cooling of buildings will continue to emerge. But again, there is no significant basis for believing that they can completely displace a continued growth in absolute demand for petroleum and natural gas.

The use of petroleum as feedstock to other industries is at a relatively low level, accounting for less than 10% of current consumption. These areas are all expected to grow significantly.

Substitute consuming systems to obviate demand growth for petroleum and natural gas also are technically feasible. They too will begin emerging at a growing rate. But these developments also will fail, even when added to the substitute fuels, to offset the increase in demand for petroleum.

Changes in consuming systems include increasing the efficiency of such systems, changing them over to use other fuels, or otherwise eliminating them from social scenes. For example, if autos and motor transportation were abolished the demand for petroleum would drop precipitously. These consuming systems will be modified. For example, regulations have already directed electrical generating plants to switch off use of fuel oil and natural gas in some areas. There is no conceivable way in which trends such as this could offset demand growth within the next twenty-five years. Nonetheless, these regulations will tend to lower the growth in demand that would otherwise occur.

Because petroleum and natural gas are fundamental supplies into systems which are interwoven intricately into the foundations of our entire economy and lifestyles not extremely flexible to immediate changeover, we forecast that the socio/political climate will remain highly favorable to responsible exploitation of petroleum and natural gas reserves beyond the turn of the century. For decades the nation has followed a development pattern which has encouraged the growth of suburbs and large metropolitan areas, bringing arm and arm a dispersed population and employment pattern within these areas. Literally tens of millions of persons have little choice other than reliance upon currently established patterns of commuting to work and for servicing their energy needs. No conceivable level of investment could substitute mass public transportation on a scale which would service these needs. It takes over ten, and more like twenty years to get an integrated metropolitan transit system operative. Even once such systems are totally operational, they generally fulfill only a modest proportion of the transportation flexibiltiy and need. The psychological and sociological position of private automotive transportation has become a deeply held value. This alone provides a pillar to the stability of political and social demand for and support of programs to continue to use petroleum and natural gas.

Comparative economic costs of developing U.S. based offshore oil and petroleum reserves will continue to evolve to a point where offshore production is not significantly hampered by cost inequities. However, the progression of exploitation will be shaped significantly by comparative costs. Reserves easily accessible and inexpensive to tap will be developed before more costly areas are exploited. These cost neutralizations may not be the sole result of market forces. World supplies may well not dictate such neutralization. But a combination of supplier controlled

prices, U.S. policy of incentives for national energy developments, and a variety of other political and social policies will combine to bring about the condition. Various instruments may be used. Governmental subsidy of development, an energy development tax along the lines of the current highway trust fund tax on gasoline, import taxes or quotas, or any combination of these and other techniques likely will be employed.

Environmental issues will grow in importance and concern, but they will not be permitted to stop or reverse the overall development of offshore reserves. Some highly sensitive locales will be restricted for offshore oil or natural gas. Also, environmental standards will continue to emerge, requiring increased costs for development and extraction. As the application of these environmental standards becomes operative in areas close to the coast and in areas of multiple use, the comparative economic feasibility will grow for tapping the remote reserves. These environmental restrictions will act as barriers to extensive unrestricted abuse of the natural environment. They will create demand pull for a variety of technologies to make possible the accommodation of both the need to exploit the oil and gas reserves and the need to retain ecological and aesthetic standards. From this type of research the concepts of ocean bottom rigs will grow in favor, being first applied in areas where multiple uses and tight environmental controls make feasible the development of the ocean bottom rig concept.

The issues rising from competing interests for conflicting uses of certain ocean areas in which oil and gas reserves are located will continue to increase and intensify. This ultimately will lead to the requirement for some form of national policy and guidelines regarding sea zones and permissible uses therein. Political, administrative and judicial procedures will be developed to provide for the processes needed to resolve the conflicts. In some instances, oil and gas reserves will be restricted from development, at least until there are no alternatives left to tap elsewhere, an eventuality which is beyond the time period of this forecast.

Some of the issues relating to conflicting uses will arise within what currently are defined as international waters. For example, the current 200-mile zone is defined only with respect to the management and conservation of fishing. We expect that the 200-mile zone will be declared fully within the national sovereignty for all development, and that it ultimately will be extended even further.

Special international procedures of the nature discussed currently in the Law of the Sea Conference ultimately will be developed for at least rhetorical purposes with respect to resolving conflicting uses outside the territorial waters of nations.

Aesthetic preservation will continue to be a major political and economic issue with respect to the tapping of oil reserves either close to coastal areas or located near currents which could bring any accidental spills into coastal areas, particularly high value recreational areas. While these concerns will affect how the resources are tapped, they will not be sufficient, except in a few selected cases, to reverse the exploitation.

By the turn of the century, the operational systems employed in an extensive network of offshore petroleum and natural gas wells will include:

- *Surface rigs which are both aesthetically "dressed up" and those which are still purely functional. These surface rigs will become more elaborate, offering better living quarters for crewmen. In some instances, surface rigs located close in to urban centers may be expanded into a form of "floating island" with some limited refining facilities and permanent apartments/buildings used as offices or other work related stations.*
- *Semisubmerged rigs employed in areas of greater depth or where, for one reason or another, the surface rig is less suitable.*
- *Bottom-based rigs involving a drilling base facility and habitat for the crew.*
- *Networks of underwater pipelines which connect wells directly into crude oil transportation systems to the refinery point.*
- *Flexible hose for connection to submersible or bottom based rigs to both regular size and super tankers.*
- *Tanker fill-up stations connected with surface rigs.*
- *An experimental refinery hook-up on the ocean floor and/or on a floating platform.*

As the bottom rig concepts are developed and pipeline systems emerge, including flexible hose pipelines capable of moving place-to-place as feeder lines into more fixed systems, the overall composition of the operational systems will begin to shift. However, we believe that these more advanced concepts will be utilized first only in the areas where controversy and/or multiple uses, combined with the richness and availability of deposits, make employment more justifiable.

Offshore Production of Coal

For at least the next two decades coal will become an increasingly important source of energy, especially for industrial processing, production of electricity, and heating and cooling of buildings. The movement to coal is already under way. Substantial investments are being made in both production and consumption systems. Coal is portrayed as available in vast quantities; it is often cited as sufficient to carry U.S. energy requirements for centuries. Nonetheless, a good deal of this coal is located deep underground, where the technology of extraction does not yet exist. Coal near the surface involves extensive strip mining entailing a host of political and environmental issues. Accordingly, the demand will grow for coal which can be acquired relatively free of major conflict.

There will be a number of offshore coal reserves discovered and plotted as a result of the general activities related to the search for petroleum, gas, and other minerals. At least some of these deposits will be located in such a manner as to provide technical and economic feasibility for extraction. There are numerous reasons to expect that geological formations under the continental shelf are roughly comparable to those found under land areas. Because coal is one of the more abundant minerals, and because the U.S. is comparatively rich in known coal deposits, it is reasonable to anticipate that similar deposits exist offshore. They will, as noted above, probably be found as a by-product result of other search activities. The technological advances in instrumentation (discussed earlier) will be a major asset in this search.

Some of these offshore coal reserves will be tapped, initially through extension from land-based shafts, and later from adaptations of current technology. Initial mining in U.S. waters will likely begin to emerge in the 1980s. Japan, the United Kingdom, Canada, Taiwan and other nations are already mining offshore coal from land-based shafts or artificial islands. These techniques will be adapted for initial applications.

As the activity emerges, rapid technological adaptations will occur for developing innovations in offshore mining techniques. These will include underwater mines equipped with living quarters and connected to surface rigs with fixed shafts into the mine or to semisubmerged or bottom rigs. Transportation of the mined coal initially will be achieved by the use of large barges and/or cargo vessels. Eventually, crushing machinery will be installed

within the offshore facilities allowing coal slurry to flow through pipelines directly into an on-shore facility. The technological streams necessary to evolve this form of offshore coal mining operations are already underway in many other areas, including: underwater habitats, scientific and commercial welding, petroleum and other offshore mining operations, and possibly later offshore coal burning electrical generating plants as a means of circumventing the air quality control standards associated with on-shore operations.

While we do not expect to see a burgeoning offshore coal industry, we do expect to see some significant operations, possibly several dozen, by the turn of the century.

Offshore Production of Uranium

The demand for uranium will intensify during the 1980s as electrical supply outlets and associated industries switch from oil and gas to other alternative energy sources. Environmentalists in their fight to prohibit nuclear power, will lose ground to the growing internal need to become energy self-sufficient. Compromises will be reached between opponents and proponents of this fuel, as a result of the implementation of considerably strict safeguards, more practical procedures to dispose of nuclear wastes, etc. Surely coal will provide an important portion of the energy in this evolving, gradually shifting environment, but nuclear energy will continue to offer temptations not found in coal. Three trends in particular will foster further U.S. consideration and utilization of the nuclear alternatives:

- Uranium provides an energy source which is relatively clean burning
- because less uranium is needed to power a given area than coal, the transport costs will be much less, in addition to the other costs associated with mining minerals.
- The U.S. will be compelled to pursue the nuclear alternative as a result of comparatively rapid growth of nuclear employment in other parts of the world, e.g., consider for a moment the space race, the arms race, etc.
- Given the lag time in construction of new electrical generating plants, it seems clear now that the U.S. will experience a significant electrical shortage by the mid 1980's. This "crisis environment" will serve as a catalytic event for the shift to the nuclear "solution."

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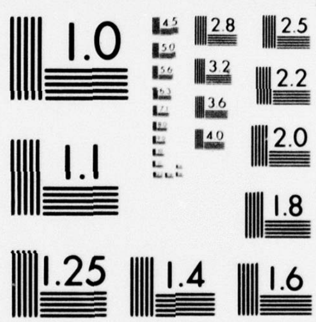


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

within the offshore facilities allowing coal slurry to flow through pipelines directly into an on-shore facility. The technological streams necessary to evolve this form of offshore coal mining operations are already underway in many other areas, including: underwater habitats, scientific and commercial welding, petroleum and other offshore mining operations, and possibly later offshore coal burning electrical generating plants as a means of circumventing the air quality control standards associated with on-shore operations.

While we do not expect to see a burgeoning offshore coal industry, we do expect to see some significant operations, possibly several dozen, by the turn of the century.

Offshore Production of Uranium

The demand for uranium will intensify during the 1980s as electrical supply outlets and associated industries switch from oil and gas to other alternative energy sources. Environmentalists in their fight to prohibit nuclear power, will lose ground to the growing internal need to become energy self-sufficient. Compromises will be reached between opponents and proponents of this fuel, as a result of the implementation of considerably strict safeguards, more practical procedures to dispose of nuclear wastes, etc. Surely coal will provide an important portion of the energy in this evolving, gradually shifting environment, but nuclear energy will continue to offer temptations not found in coal. Three trends in particular will foster further U.S. consideration and utilization of the nuclear alternatives:

- Uranium provides an energy source which is relatively clean burning
- because less uranium is needed to power a given area than coal, the transport costs will be much less, in addition to the other costs associated with mining minerals.
- The U.S. will be compelled to pursue the nuclear alternative as a result of comparatively rapid growth of nuclear employment in other parts of the world, e.g., consider for a moment the space race, the arms race, etc.
- Given the lag time in construction of new electrical generating plants, it seems clear now that the U.S. will experience a significant electrical shortage by the mid 1980's. This "crisis environment" will serve as a catalytic event for the shift to the nuclear "solution."

Offshore production of uranium will emerge as increasingly attractive as the prominence of nuclear energy takes shape over the next two decades. The fourfold increase in the price of uranium over the past decade alone has caused scientists to disregard the feasibility of extracting uranium from seawater. Further refinement of the chemical engineering technologies and techniques necessary to extract uranium (in addition to other minerals and chemicals) is likely during the next decade; given the continuing "skyrocket" in the price of uranium extracted from land-based sites, seawater extraction can become economically competitive within a decade. The siting, construction, and operation of nuclear power plants offshore during and before the end of the 1980's are forecasted within this chapter. Given this development it seems plausible that as extraction techniques are refined, nuclear offshore plants will become uranium self-sufficient; seawater will be processed within these floating plants to derive uranium fuel for direct use.

Kelp Biomass

The use of biomass energy will be an important feature of land-based energy development alternatives, e.g., human/animal/solid wastes, but it will not be a significant feature of the late 20th century marine environment. We do expect a few experiments to cultivate, harvest, and process kelp on the West Coast to continue for some time, yet demand systems for the end product of kelp production and processing, namely methane gas, will be satisfied from less costly biomass counterparts found on land. In spite of this activity forecast, if present consideration and conceptualization of using alcohol to power automobiles becomes feasible, the future for kelp would change dramatically. The transformation from gasoline-powered engines to engines powered by alcohol, however, could be quite a lengthy period given public and institutional constraints; beyond 2000 the probability for alcohol powered engines will sharpen as well as engines powered by solar energy.

Offshore Production of Electricity

Many of the energy underwater activities listed at the beginning of this chapter are related to the offshore production of electricity. The future activities such as ocean thermal energy conversion, ocean currents, wave power, and offshore nuclear plants are all contingent upon the common overriding issue of whether offshore production of electricity will be needed.

As was discussed at the beginning of this vignette, there are a number of reasons to place a very high probability upon the emergence of a significant level of interest and activity in the offshore production of electricity. This new offshore industry, by virtue of its novelty and the priority and national concern placed upon it for adequate energy from self-sustaining sources, will be pursued initially from an experimental context. *An atmosphere of investigation, fueled by an extensive federal government budget for energy alternative experimentation and development programs, will lead to a variety of enterprises in offshore production which would not otherwise be undertaken.* Several states are likely to see the development of an offshore electrical potential as an important source for state economic development, especially those states which are populous and cannot readily construct nuclear plants on land. These states will see offshore production as a means of regional self-reliance, and possible export.

Given the liklihood for offshore production, we expect the offshore electrical production industry to emerge and expand rapidly. The pattern of emergence will begin with source-specific experiments such as an ocean thermal energy conversion demonstration project, an offshore nuclear power plant, or a single offshore effort to capture ocean currents. Even as these concepts emerge, ideas for multipurpose conversion plants are likely to develop. A plant which could employ currents, thermal gradation, solar and wind collection, and wave power might prove to be conceptually attractive and technically feasible. This "economics of integration" may well change the overall cost feasibility of some offshore energy activities which alone would not prove justifiable. From this viewpoint, there is the notion of larger offshore energy complexes; these in turn would serve as the hub for offshore industrial centers. In spite of this favorable picture for offshore electrical production, we believe that these conceptualizations will reach only a nascent stage by the turn of the century. During the forecast period in this study, we foresee the initial steps to be more modest. Some further details are outlined below.

Ocean Thermal Energy Conversion

The present U.S. government priority for the development of OTEC will assist in the short range experimentation and eventual application of this energy alternative. The front end costs will be absorbed through federal subsidies, and

during the 1980's, the feasibility of the concept will be proven viable for electrical generation. Use will be localized at first, but commercial acceptance and application of the process will take place before or during the early 1990's. The considerably long construction lead time of these facilities will inhibit moderate to rapid growth of OTEC plants, yet they will make a small but growing contribution to national energy sources by the year 2000. Thereafter, OTEC could become an important source of electrical generation for rapidly increasing coastal population centers.

Tidal Power Conversion

Perhaps the key driving force for tidal power is technical feasibility proven by demonstrations of this concept in other parts of the world. France and the Soviet Union already have tidal power stations operating, and although their economic feasibility has been contested by some analysts, long term costs will bear witness to the efficiency of these stations. The persistence and regularity of the tides, in addition to the overall attractiveness of the concept where geophysical perspectives apply, will accelerate further consideration, design, and employment of tidal power stations in many parts of the world.

Within the U.S., institutional cautiosness over investment in tidal power will impede rapid, widespread growth of plant construction, yet tidal power conversion will find applicability within or near U.S. waters. It is highly likely that public sector subsidies will absorb early developmental costs. Thereafter, a consortium of nations and/or companies will team up to finance, construct, and operate a tidal power plant. The most ideally suited geophysical area for employment of a tidal station exists in the Canadian Bay of Fundy. Although there are certain areas within U.S. territorial waters that are suitable for tidal power conversion, e.g., off the coast of Maine or Baja, California, a joint Canadian/U.S. venture in the Bay of Fundy seems more plausible given the better geophysical phenomena in this body of water and the greater availability of capital from two neighboring industrialized nations. Construction of this site will take place before the year 2000, but the actual operation and distribution of the power generated will not be a feature in the national energy picture before the end of the century. After 2000, New England would receive substantial benefits from Fundy's tides.

Wave Power Conversion

The conversion of ocean waves to a usable energy form will not take place on a large scale during this century. Despite the attractiveness of waves as a clean, renewable energy alternative, economic and technical feasibility of large-scale systems has not been tested. Considerable technological breakthroughs are still needed, for example, to improve power density per unit. The demonstrated feasibility of small-scale systems will lead gradually to more improved modes of application. The transition from wave-powered buoys, to the propulsion of seafaring vessels, or to localized generation of electrical power is conceivable, but the unsteady geophysical requirements for most nations will impede the large-scale use of waves.

Offshore Collection of Solar Heat

Solar heating and cooling of buildings (residential, commercial, and industrial) will find significant application in our land-based environment over the remainder of the century; solar cell technology will emerge economically competitive before the end of the next decade. The harnessing and conversion of the sun's rays will become proportionally a much large share of our nation's energy sources, and an even larger proportion within selected regions of the country, i.e., the sunbelt states.

In spite of the favorable outlook for solar energy on land, it seems highly unlikely that anything other than experimental projects for offshore solar collection will be employed in this century. Some of the negative forces working against offshore energy include:

- The rising costs of floating and/or fixed pile platforms in the marine environment. It simply would be less expensive to deploy solar collection structures on land.
- The unattractive, aesthetically offensive appearance of offshore structures. Although this barrier can be offset partially through "platform cosmetics" such as that employed off the West Coast for oil production platforms, the costs for undertaking such dressing up further inhibits feasibility.
- The conflicting uses for the area selected for solar collection. A host of disputes are likely to emerge over whether the tract of ocean space should be used for oil and gas exploration, recreation facilities, etc.

Yet as offshore habitation and production sites appear more frequently in the marine environment, solar panels and collectors on these floating sites are likely to be employed to capture the natural energy of the sun to provide at least some of the energy needed by inhabitants or workers on these structures.

Thus solar collection offshore will find application for offshore operations connected with other purposes, but it is unlikely that solar collection offshore will be extensively employed to capture and distrubute energy to land-based systems.

Offshore Wind Energy Conversion

Efforts to harness and convert wind energy for use in human consumption systems are likely to receive increasing attention during the next two decades, with some notable achievements taking place along the way. The conversion of wind into useful energy generally will find application in small population centers with only localized distribution networks.

It is likely that many of the same fortunes which will befall offshore solar collection of heat will be valid for the offshore collection of wind. The costs of constructing and placing literally hundreds of floating windmills offshore and the unappealing sightliness of these structures will inhibit widespread marine application. In addition, the intermittent nature of wind threatens a continuous, stable flow of energy to end-use consumption systems.

It is possible that offshore wind energy conversion systems will emerge in the marine environment before or during the turn of the century. We would expect that some experimental sites would be constructed and under operation along coastal margins of the U.S., but these structrues will supply only a small portion of coastal population energy needs, and usually will serve only small coastal towns. On the other hand, it seems likely that the United Kingdom will pursue seriously the concept of harnessing winds in the North Sea as the century draws near its end and Britain's oil reserves diminish. It is possible that a consortium of nation states will explore the feasibility of harnessing Antarctic's unusually high wind velocities; yet the fraternity among these nations is likely to cease as debates over the distribution of the harnessed energy emerge. Disputes over how and where the wind energy should be distributed are likely to stagnate application more than the construction time needed to build the wind roters in this continent.

Offshore Nuclear Power

As nations turn increasingly to nuclear power during the 1980's (as previously forecasted in this report) offshore siting of nuclear power plants

will become more attractive. Problems related to safety, health, and adequate locational siting for nuclear plants will become a paramount issue. It is conceivable that at least one major accident involving a nuclear power plant on land will take place which will further catalyze the movement to site facilities such as these distant from population centers. We believe that a number of offshore nuclear power plants will be under construction, and perhaps in complete operation, before 1990. The siting and operation of these plants offshore will entail a fairly fierce regulatory debate, the institution of a host of management and control procedures, and a persistent public sector monitoring and inspection process.

Although the number will be comparatively small, we do expect at least a few offshore industrial production plants, using energy sources from underneath the seabed directly for consumption, to emerge during the forecast period. There are numerous industries which are environmentally undesirable in land-based sites. It is probable that the unappealing nature of many kinds of industrial processing in our land-based environment will continue. This trend, coupled with the siting of nuclear power plants and the technological/procedural spillover this phenomena will have for other plant sitings, will assist substantially in initiating some experimental and/or demonstration projects for offshore industrial plants. Despite the fact that the number will be insignificant, the concepts employed in undertaking this effort will require the development of policies, regulations, and management structures and concepts considerably innovative and utilizable for the expansion of offshore siting of industries, utilities, and perhaps even residential complexes.

Ocean Current Power

The short-to-mid range future for harnessing underwater ocean currents as an alternative energy source does not bode a favorable picture. The comparative economic costs, extremely limited geophysical locations within U.S. territorial waters, and institutional hesitancy to invest in a seemingly risky venture are working concurrently to inhibit development of the concept.

The longer range future for ocean current use as an energy source appears somewhat more favorable, yet even beyond the year 2000 probabilities for employment in the U.S. are low. Technological spillover from other commercial activity in the marine/underwater environment should prove usable in harnessing and converting ocean currents for power. Anticorrosion materials development will make feasible the long term placement of rotor generators under water to

capture currents; emerging engineering techniques will assist the operation of these underwater activities. In spite of these optimistic developments, it still seems unlikely that the sole primary current within close proximity of the U.S. coast, i.e., the Florida Current, will be harnessed. Other energy alternatives ultimately appear more alluring for the southern peninsula of Florida to pursue, for instance solar energy. A good deal of consideration will be given to currents by other nation states. Two developing nations rich in petrodollars with small and rapidly diminishing petroleum reserves left have both the needed investment capital and geophysical requirements to utilize ocean currents: Venezuela's Equatorial Counter Current and Nigeria's Guinea Current. Japan's heavy dependence on petroleum imports could be offset partially if this industrial nation devised and constructed an underwater ocean power plant to capture the steady strong movement of the Koroshio Current off the country's southern islands.

Underwater Geothermal Energy

Although the technical and economic feasibility of geothermal power extraction will be understood and pursued in the land-based environment, the scope and magnitude of marine-based activity toward this end will be limited. There will be searches and an inventory of potential underwater geothermal sites, but we do not expect the U.S. or most nations in the international community to pursue underwater geothermal. Cost efficiencies, the nonrenewable nature of geothermal deposits, the unanswered environmental effects of exploiting these deposits, and the overall greater appeal of other energy alternatives will each work against either widespread or moderate development of this potential energy source. Within the forecast period we would expect at least some offshore geothermal drilling operations, probably in the tectonic plate area off the West Coast.

Salinity Power Gradients

In spite of the large magnitude of potential energy which could be harnessed vis-a-vis osmosis to capture salinity gradients for electrical generation, the conceptual stage of this alternative requires a wealth of additional studies to prove practical for the U.S. Many economic, technical, and environmental questions remain unanswered. Some government-sponsored research in the area is already under way, and during the 1980's we will have

some answers to these many questions. But the likelihood that this alternative will provide even a small proportion of our nation's energy needs before the end of the century is low, even if these results during the next decade are favorable. We believe that the possibility exists that one or more salinity gradient power stations will be operating in the Mississippi Delta region by the 1990's, but these plants will be small-scale demonstration projects, perhaps providing electrical power for the coastal areas, but the populations utilizing this energy form will not be significant in size.

Deepsea Pressure Power

The mere fact that this energy alternative in the marine environment has very limited geophysical application will inhibit the development of deep-sea pressure power for use in the U.S. The scantiness of deep ocean trenches, in addition to their great distance from the U.S., will impede further technical and economic feasibility studies for this energy alternative; there are simply too many other feasible energy forms for the U.S. to pursue.

There is a possibiltiy that Japan will explore further this approach, but the future of deepsea pressure power is contingent upon the success of other energy systems. Given the close proximity of many deep ocean trenches to Japan, pressure power is likely to receive some attention in this country. Yet Japan will pursue other alternatives which have a greater feasibility, consume less cost to develop, and are more practical for widespread application, e.g., solar collection, wave generation, etc.

FIGURE 4-3: TAILORED VIGNETTE - ENERGY

FORECASTED DEVELOPMENTS	PROBABILITY/TIMING 1981-85	1986-92	1993-2000
ENERGY INTENSE ECONOMIC GROWTH AND SOCIAL DEVELOPMENT IS CHOSEN AS FUNDAMENTAL COURSE FOR INDUSTRY AND SOCIETY	H	H	H
SEARCH FOR ALTERNATIVE ENERGY SOURCES CONTINUES TO GROW	G	H	H
• NEED FOR GREATER ENERGY INDEPENDENCE INCREASES	H	H	H
• REALIZATION OF EXHAUSTIBLE NATURE OF FOSSIL FUELS	G	G	H
U.S. DOMESTIC ELECTRICAL GENERATION CAPABILITIES/CAPACITY BECOME MAJOR AREA OF CONCERN AND CRISIS	G	H	L
SYSTEMATIC DISCOVERY/INVENTORY OF EARTH'S TOTAL ENERGY RESOURCES/RESERVES EVOLVES AT A RAPID PACE	L	G	G
DEMAND FOR OIL AND GAS INCREASES IN ABSOLUTE TERMS, AND SUSTAINS THE NEED/DEMAND FOR OFFSHORE DEVELOPMENT OF THESE RESOURCES	H	H	H
ENVIRONMENTAL ISSUES/DEBATES WILL INCREASE, BUT OFFSHORE OIL AND GAS RESERVES WILL CONTINUE TO BE PURSUED	H	H	H
• SOME HIGHLY SENSITIVE LOCALES WILL PROHIBIT OFF-SHORE OIL AND GAS EXPLORATION AND EXTRACTION ACTIVITY	H	H	G
• ENVIRONMENTAL STANDARDS WILL CONTINUE TO EMERGE AND REQUIRE INCREASED COSTS FOR COMMERCIAL DEVEL-OPMENT/EXTRACTION	H	H	H
• COMPARATIVE ECONOMIC FEASIBILITY TO TAP RESERVES FARTHER FROM COASTAL MARGINS INCREASES	L	G	H
• COMPETING INTERESTS FOR CONFLICTING USES OF CERTAIN MARINE AREAS INTENSIFY	G	H	H
• NEED FOR NATIONAL POLICY AND GUIDELINES FOR SEA USE IS REINFORCED	H	H	H
• OPERATIONAL SYSTEM EMPLOYED FOR EXPLOITING OFFSHORE OIL AND GAS ENTAILS:			
• SURFACE RIGS "DRESSED-UP" TO MEET ENVIRONMENTAL/AESTHETIC GUIDELINES	H	G	G
• SEMISUBMERGED RIGS	H	H	G
• BOTTOM-BASED RIGS WITH DRILLING FACILITIES AND TEMPORARY WORKING/LIVING HABITATS	L	G	H
• UNDERWATER PIPELINES CONNECTED TO OFFSHORE WELLS FLOWING OIL/GAS DIRECTLY TO REFINERY POINTS	H	H	H
• FLEXIBLE HOSES CONNECTED TO OIL TANKERS FROM BOTTOM RIGS	G	H	H
• EXPERIMENTAL REFINERY HOOK-UP ON OCEAN FLOOR AND/OR A FLOATING PLATFORM	M	L	G
COAL BECOMES INCREASINGLY IMPORTANT SOURCES OF ENERGY IN U.S., AND SERVES AS CATALYST TO EXPLORATION AND DEVELOP-MENT OF OFFSHORE COAL PRODUCTION SYSTEMS			
• OFFSHORE COAL RESERVES ARE PLOTTED IN U.S. TERRI-TORIAL WATERS	L	G	G
• BECOMES TECHNICALLY AND ECONOMICALLY FEASIBLE TO EXTRACT	G	G	H

M = minimal G = good
L = low H = high

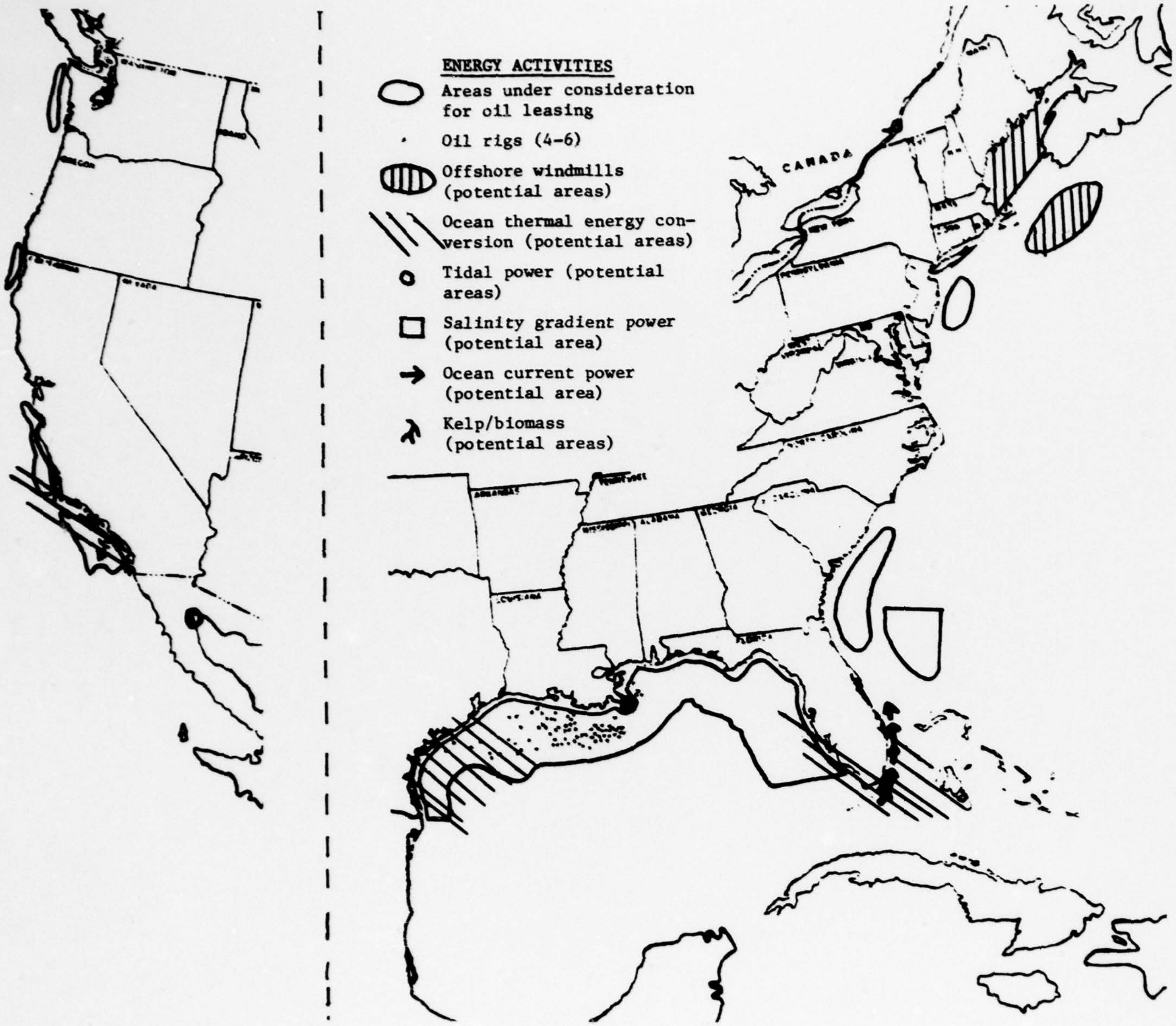
FIGURE 4-3: TAILORED VIGNETTE - ENERGY (Continued)

FORECASTED DEVELOPMENTS	PROBABILITY/TIMING		
	1981-85	1986-92	1993-2000
• ARE EXTRACTED UNDERNEATH SEABED FROM LAND-BASED SHAFTS	G	G	H
• ARE EXTRACTED FROM UNDERWATER MINE SITES	L	G	H
• SITES ARE EQUIPPED WITH TEMPORARY LIVING QUARTERS	M	L	G
• SITES ARE CONNECTED TO SURFACE RIGS	M	L	G
• RESERVES LOADED AND TRANSPORTED IN BARGES AND OTHER BULK CARGO VESSELS	M	L	G
• COAL IS CRUSHED IN OFFSHORE FACILITIES AND TRANSPORTED TO LAND PROCESSING FACILITIES VIA A SLURRY PIPELINE NETWORK	M	L	G
OFFSHORE URANIUM PRODUCTION BECOMES INCREASINGLY ATTRACTIVE DUE TO:			
• OVERALL INCREASING SOCIETAL/INDUSTRIAL DEMAND FOR NUCLEAR FUEL	G	H	H
• SKYROCKETING PRICE OF LAND-BASED URANIUM SUPPLIES	H	H	H
• TECHNICAL AND ECONOMIC COMPETITIVENESS OF URANIUM EXTRACTION VIA CHEMICAL PROCESSES	L	G	H
• DETERMINATION OF SIZABLE SEABED DEPOSITS OF URANIUM	M	G	G
EXPERIMENTATION AND USE OF LAND-DERIVED BIOMASS ENERGY WILL INCREASE	G	G	H
• A FEW EXPERIMENTS WILL BE UNDERWAY TO CULTIVATE, HARVEST, AND PROCESS KELP ON THE WEST COAST	L	G	G
• CONSIDERATION OF ALCOHOL TO POWER TRANSPORTATION VEHICLES FACILITATES FURTHER CONSIDERATION/UTILIZATION OF KELP	M	L	G
HEIGHTENING ISSUES/CRISES RELATED TO ELECTRICAL PRODUCTION PRECIPITATE GREATER AMOUNT OF OFFSHORE ACTIVITY AIMED AT GENERATING ELECTRICITY	G	H	L
PUBLIC SECTOR BUDGETS INCLUDE EXTENSIVE AMOUNT OF PROGRAM FUNDS FOR VARIETY OF ALTERNATIVE ENERGY FORMS TO PRODUCE MORE ELECTRICITY	H	H	H
• OTEC BECOMES PARTIAL SOURCE OF ELECTRICAL GENERATION FOR SOME COASTAL MARGINS	G	H	H
• TIDAL POWER CONVERSION FINDS APPLICATION WITHIN OR NEAR U.S. WATERS	L	G	H
• NATIONS OTHER THAN U.S. ARDENTLY PURSUE WAVE POWER CONVERSION	G	G	H
• U.S. EMPLOYS NETWORK OF WAVE-POWERED BUOYS	G	H	H
• SOLAR APPLICATION IN OFFSHORE ENVIRONMENT REACHES EXPERIMENTAL STAGE	H	H	G
• SOLAR PANELS/COLLECTORS EMPLOYED OF OFFSHORE STRUCTURES FOR MULTIPURPOSE ELECTRICAL/ENERGY PRODUCTION	M	G	G
• WIND ENERGY CONVERSION HAS LIMITED OFFSHORE APPLICATION	G	H	H
• OFFSHORE NUCLEAR POWER PLANTS CONSTRUCTED IN U.S. WATERS	G	G	H
• NATIONS OTHER THAN U.S. PURSUE HARNESSING OF OCEAN CURRENTS TO PRODUCE ELECTRICITY	L	G	H
• VERY LIMITED UNDERWATER GEOTHERMAL ENERGY ACTIVITY OFFSHORE	L	H	G

(Continued)

FIGURE 4-3: TAILORED VIGNETTE - ENERGY (Continued)

FORECASTED DEVELOPMENTS	PROBABILITY/TIMING 1981-85	1986-92	1993-2000
• FURTHER STUDIES ARE UNDERTAKEN TO EMPLOY SALINITY GRADIENTS TO PRODUCE ELECTRICITY	L	G	G
- YET THIS ALTERNATIVE WILL NOT BECOME A PRIMARY OR SECONDARY SOURCE OF ENERGY FOR U.S.	H	H	G
• TECHNICAL AND ECONOMIC FEASIBILITY FOR DEEPSEA PRESSURE POWER FOR U.S. DOES NOT MATERIALIZE	H	H	H
- YET AT LEAST ONE OR MORE OTHER NATIONS UNDERTAKE SIGNIFICANT TESTING/EMPLOYMENT OF THE CONCEPT	M	L	G


ENERGY ACTIVITIES
Areas under consideration for oil leasing
Oil rigs (4-6)
Offshore windmills (potential areas)
Ocean thermal energy conversion (potential areas)
Tidal power (potential areas)
Salinity gradient power (potential area)
Ocean current power (potential area)
Kelp/biomass (potential areas)
CANADA

CHAPTER 5: MINERAL MINING OTHER THAN FOSSIL FUELS

DEFINITION

Underwater mineral activities include the extraction of all nonliving material from beneath the surface of water. However, for the purposes of this discussion, basic energy materials which fit this definition and are formally a component of mineral mining are included in the previous chapter dealing with energy related activities.

The underwater overall/mineral mining or extraction activities are classified into three basic classes. There are sixteen specific mineral mining activities within these three classifications; two of which are energy related. See Figure 5-1.

FIGURE 5-1: UNDERWATER MINERAL EXTRACTION ACTIVITIES

Basic Classes	Specific Activities
Beneath Bottom	Oil and natural gas (see Chapter 4 on Energy) Coal (see Chapter 4 on Energy) Sulphur Hard rock and other minerals Fresh water aquifers
Bottom "Collection," "Stripping," and "Pitting"	Sand and gravel Limestone and shell Placers Manganese nodules Red clay/ooze Hard rock Phosphorite Metaliferous mud
In Water	Chemical extraction Desalination Icebergs

BACKGROUND

Some offshore mining activities are presently operated, such as the extraction of sand and gravel. But expanded development of offshore mining activities remains for the furture. Essentially those factors discussed in the last chapter on energy, which will catalyze offshore exploitation are operative for underwater mining or extraction activities.

Within the U.S., land supplies of many minerals are dwindling and these minerals are approaching projected shortage levels. Minerals located outside the U.S. must be imported. U.S. independence and stability of supply are important for an increasing number of critical minerals uses as raw materials in our economy. General attention to the marine environment, plus the search for alternate mineral reserves is leading to a growing awareness that the marine environment contains extensive reserves of important minerals.

Technological capabilities and related constituencies/interest groups are increasing, and the overall future in underwater activities related to mineral resources extraction promises to be dynamic in a variety of areas.

FUNCTIONAL SYSTEM

There are six basic categories of functional components or systems associated with these activities. These functional components carry some of the same nomenclatures and definitions discussed in Chapter 4 on energy operational systems. However, as will be shown later, the substantive information contained within these generic categories is significantly different and quite unique.

- End Use Consumption Systems: Underwater mineral mining operations are almost exclusively done to support some land based operation or industry. One of the driving roces for marine mining stems from an increasing inadequacy of land-based sources of minerals considered critical to the U.S. and other advanced economies. Based upon currently known deposits of minerals found offshore, these end-use systems include construction and industrial raw materials, precious metals and gems, fertilizers and agriculture, and fresh water systems.

- Offshore Mineral Reserves/Potential: At the other end of the operational system spectrum are offshore mineral reserves known to exist and the general professional judgment that there are many other reserves not yet charted. These rather large potential sources apply to all of the minerals enumerated in the definition.

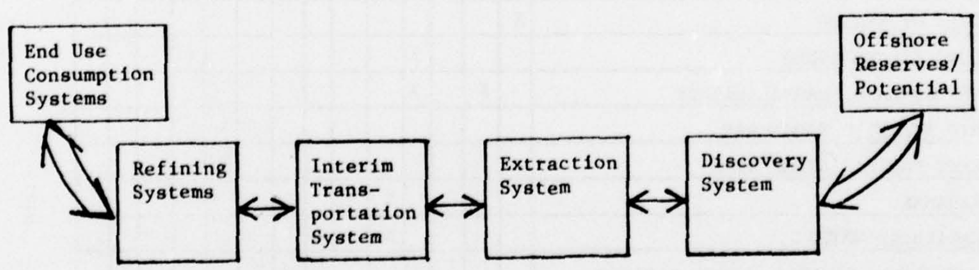
• Discovery Systems: All mechanisms utilized to detect and quantify mineral deposits including sampling methods, sensing techniques, and geological instrumentation systems are part of this general category.

• Extraction Systems: Extraction systems are all mechanisms to isolate the desired commodity from the ocean environment. Dredging techniques, drilling mechanisms, and purification methods are typical representatives of present extraction technologies.

• Interim Transportation Systems: After extraction, in most traditional resource systems, the product has to be transported to a refining or processing facility. This aspect of the opeational system is common to both land and water extraction procedures. The mode of transportation will vary according to the material that is removed; in some situations a pipeline will be applicable whereas another situation may demand the use of a vessel.

• Refining System: Most extracted materials are in a crude form and require a purification step. The processing mechanisms that upgrade or refine minerals comprise this category.

FIGURE 5-2: FUNCTIONAL COMPONENTS OF THE OPERATIONAL SYSTEM



GEOPHYSICAL PERSPECTIVES

Each of the specific underwater mineral activities has different geophysical situations. However, there are common features which must be fulfilled. These include:

• The physical location of the minerals is determined by where nature has provided them. These locations cannot be changed by human intervention.

• The operational environment where the deposits are found must be compatable with the level of technological development which can permit extraction to occur.

Figure 5-3 outlines the specific geographical areas where current knowledge suggests these mineral mining activities are most likely to occur. A graphic representation of these mineral locations is found on page 5-17.

FIGURE 5-3: GEOPHYSICAL PERSPECTIVES: MINERAL MINING

GEOGRAPHICAL LOCATIONS	MINERALS: SULFUR	HARD ROCK	FRESH WATER AQUIFERS	SAND AND GRAVEL	LIMESTONE AND SHELL	PLACERS	MANGANESE NODULES	RED CLAY/OOZE	PHOSPHORITE	METALFERIOUS MUDS	CHEMICAL EXTRACTION	DESALINATION	ICEBERGS	BARITE
U.S. TERRITORIAL/ECONOMIC ZONE														
CONTINENTAL SHELF AREAS OF:														
GULF	X				X									
ATLANTIC				X					X					
PACIFIC														
ALASKA		X					X							X
HAWAII														
GEORGES BANK AREAS														
SOUTHERN CALIFORNIA COAST				X					X					
FLORIDA COAST					X	X			X					
GULF OF MEXICO	X													
LONG ISLAND SOUND				X										
NEW ENGLAND COASTAL WATERS		X		X										
MID ATLANTIC RIDGE AREA										X				
EAST PACIFIC RIDGE AREA										X				
BAHAMAS					X									
CARIBBEAN WATERS					X									
NORTHEAST PACIFIC, SOUTH PACIFIC								X						
OTHER WATERS														
RED SEA										X				
ICELANDIC WATERS					X									
U.K. OFFSHORE				X										
CANADIAN COASTAL AREAS:														
ATLANTIC														
PACIFIC														
GREENLAND														X
ANTARCTIC														X

FIGURE 5-4: TAILORED FRAMEWORK: UNDERWATER ACTIVITES RELATED TO MINERAL MINING

Basic Concepts	Key Driving Forces	Key Barriers	Obviating Factors
• End use consumption systems	• Demand for minerals greater than land based supply	• Comparitive economic costs	• suitable technological substitutes to fill demand
Construction aggregates	• Need for greater national supply independence	• Environmental risks	• Overriding loss of socio/political feasibility
Fertilizers	• Growing awareness of underwater potential	• Conflicting uses	
Industrial processing	• Advancing technologies to locate and exploit	• Geophysical requirements	
Precious gems and metals	• Technological feasibility	• Risks to public safety and health	
Fresh water systems	• Enhancing U.S. technological leadership	• Uncertainty of technological capabilities	
• Offshore reserves		• Jurisdictional regulation environmental uncertainty	
Geologic determination of supply		• Land based sources adequate to meet demand	
• Discovery systems			
Sensing instrumentation			
Sampling techniques			
Assays			
• Extraction systems			
Dredging technologies			
Purification methods			
• Interim transportation systems			
Ocean vessels			
Pipelines			
• Refining system			
Land based			
Ocean based			

TAILORED FORECASTS

BASIC CONCEPTS

End-Use Consumption Systems

Current and forecasted demand for mineral resources depends upon the following basic technological systems:

- Construction aggregates--the materials utilized by the building industry to support structures and pave roads
- Industrial processing--the utilization of specific metals for industrial hardware and production facilities
- Precious metals and gems--the minerals that have unique social value for their beauty and rarity
- Fertilizers and agricultural industry--the transformation and purification of minerals particularly the use of phosphates and limestone to create agriculture fertilizers
- Fresh water systems--all known use of fresh water particularly for agricultural irrigation

Offshore Reserves/Potential

The available supply of underwater mineral resources has at some level a finite capacity. Although the deposits thus far assayed seem to offer tremendous mining opportunities, the ultimate description of a nonrenewable supply stream is appropriate. There are no known concepts whereby the total reserves of mineral deposits could be augmented. (It should be noted however, that some scientists have hypothesized extracting minerals other than salt from the ocean water by chemical/physical means.)

Discovery Systems

Detection systems for minerals have two primary purposes; to locate the deposits and ascertain their composition. Traditionally, mineral deposits have been analyzed by some sampling mechanism which extracted the mineral from the seabed, and brought it out of the ocean environment for visual and chemical evaluation. Present technologies are directed to elimination of this latter step. Seismic, electric, magnetic and optical sensors are now in use or under development to supplement and replace older methods of direct sampling. In the future, scientists will be able to accurately map the size, location and composition of mineral deposits without any direct extraction step.

Extraction Systems

With the exception of the "water" extraction activities most mineral extraction systems are defined by the mechanisms required to dislodge and collect an ocean mineral deposit from the seabed and the transport of that mineral to a collection or processing facility.

Near-shore deposits are removed conventionally by dredging systems. At low depths a bucket ladder dredge is employed which simply rotates a series of scoops from a surface vessel to the ocean bottom and back to the ship. As dredging systems go to greater depths, hydraulic pumps, which act as large industrial vacuum cleaners are utilized.

Technological concepts for improvements include new corrosion resistant materials, quicker rates of extraction, the ability to dredge in a variety of disruptive environments, and the development of underwater equipment that will withstand bending and shearing stresses. The required innovations to meet these objectives will stem from new emerging technologies which include:

For Shallow Water--

1. Semisubmersible dredges--Conceptually these devices provide greater ocean stability and operate at deeper depths than dredging systems presently employed. These systems will, in times of nonuse, reside 15 feet below the ocean surface and during operations to increase the system's stability be flooded and remain 25 feet below the surface.

2. Submersibles dredges--These systems are for near shore excavation of sand and gravel and are employed in depths ranging from 20 to 100 feet, and can be remotely controlled or manned.

3. Dredge head control mechanisms--Will include the utilization of television cameras to direct dredging procedures, underwater stabilizers to reduce the dredge head's movement in response to stresses such as waves of currents, remotely controlled programs which operate dredges in specific deposit pockets and internal hydraulic pumps to increase efficiency rates of extraction.

For Deep Water and Nodule Mining--

1. Hydraulic lift systems--The dredging mechanisms work like a large scale underwater vacuum cleaner in which the nodules are lifted through a pipeline to the transporting vessel. This system has successfully been tested at depths of up to 3000 feet.

2. Continuous bucket-line systems consist of a string of buckets that are lowered and dragged along the bottom and return to a given vessel with the nodules. This procedure has successfully been tested at 4000 meters.

Interim Transportation Systems

Two basic concepts exist by which extracted minerals from the ocean can be transported to the land. Pipeline transmission which now operates as a vehicle for direct land refill potentially offers spin-off technologies and developments. For example, coastal extraction of phosphorite may be directly injected in a pipeline which leads into a fertilizer plant. The pipeline would be flexible and bendable enabling the dredge head to cover a wide area of deposits. This approach eliminates the need for loading and unloading of vessels.

The second approach will see developments in the traditional transportation mode of direct vessel usage. To improve the economics of transporting large quantities of mined resources, vessel size may expand to accommodate extraction efficiency. In this perspective, the development of a super tanker for mineral cargoes could be an emerging technology.

Refining Systems

Most minerals extracted from the offshore environment require some form of further processing. For purposes of this analysis, the primary distinction of importance is whether the refining process facilities are located onshore or offshore. For onshore refining processes, the significance to the underwater activities forecast is primarily related to the methods of interim transportation discussed above.

For offshore refining process facilities many more implications are involved. It is potentially possible to locate refining processes either on surface vessels which move with the extraction systems, or in semi-submerged or bottom based facilities.

There are concepts currently hypothesized whereby fertilizer plants, which are large consumers of energy, might be located offshore adjacent to or incorporating an energy generation capability and accepting the offshore raw materials directly into the plant rather than transporting to a shore-based vacility.

As was discussed in the previous chapter on energy, concepts for ocean floor refineries of various types have been suggested.

Still other concepts express the possibility of offshore industrial complexes usually harnessed to floating platforms or artificial islands.

TAILORED VIGNETTE

Many of the basic issues associated with the overall choice of continued industrial intensity which were discussed in Chapter 3 are equally applicable to the general area of minerals mining. As was indicated in that chapter, we anticipate that the basic choice will be for continued industrial intensity within the context of a growing need for more national control over the stability of supply of major raw materials both in terms of availability and cost. Since these forces are emerging at the same time that continental land based supplies within territorial jurisdictions controlled by the U.S. are becoming more scarce, we anticipate that *the general national need for development of the underwater mineral reserves will continue to emerge and will become increasingly identified as a matter of important national policy and priority.*

The demand for this exploitation/development of underwater mineral reserves will not be uniform across all categories. Excavation will occur selectively. The prioritization of will emerge in terms of the overall needs of the national economy rather than in terms of the vested interest and desires of the offshore marine mining industry. Since the stimulus of governmental incentives and regulation will be an important component of the offshore mineral developments, national priorities and national governmental policies will be of special significance to shaping the structure and evolution of the offshore mining industries.

We have already discussed in Chapter 3 the offshore mining activities for uranium. As was seen in that chapter, *petroleum and natural gas are seen as a key driving wedge which will spearhead the overall offshore minerals industry. Another motivating factor will be the need for currently mined minerals for which there is a growing demand but a dwindling land-based supply.* Examples include sand, gravel, limestone and shell. *The demand for minerals which are not presently mined from the ocean, but have a strategic or economic significance will be actively pursued.* Examples include copper and manganese such as is found in ocean nodules.

In all three of the above categories, the comparative cost disadvantages presently associated with offshore development will gradually be neutralized. This will result from many factors. Discovery techniques will be more precise and often operated by scientific teams. Special governmental incentives for materials regarded to be especially important to the overall national economy are another factor. Since government owns the seas, and the mineral rights can be

made available on a variety of terms is still a third ingredient. The general desirability to many states and vested interests to having the exploitation of offshore minerals opened up through governmental leadership and investment in initial technological advances will also contribute. Finally, the rapidly excalating prices associated with resources which are land based and which must increasingly be transported from other nations and continents will also tend to rapidly close the cost/effectiveness gap between the onshore and offshore mineral reserves within the categories discussed above.

Suitable substitutes for various minerals will be technically feasible in some end-use systems. However, the diverse end products that minerals are incorporated into, the continued reliance upon them in sophisticated electronic systems, and their utilization in new technologies will be sufficient to outweigh the impact on demand fostered by the development of substitutes.

The agricultural sector is, of the listed end-use consumption systems, the most likely to be modified in our forecasted period. New genetic advances in nitrogen fixation may curtail the reliance farmers presently have on chemical fertilizers. Environmental pressures and regulation will increase the concern about the long term harmful effects of these agents. These events may reduce some of the interest in the mining of ocean minerals, such as limestone and phosphorite, that have direct application to the fertilizer industry.

Because minerals are fundamental aspects of our national economic, technical and agricultural base, the socio/political climate will remain favorable to underwater exploitation for mineral resources.

For decades the U.S. has developed a worldwide technological and agricultural leadership. The mineral supply systems upon which this leadership is partially founded has been relatively consistent. Should discontinuities develop either from diminishing land supplies or from the lack of available imports, the internal motivation to exploit our own offshore resources would be enhanced. This would be manifested by federal investment in both private and public ventures.

Environmental issues will escalate in national importance and concern but they will not impede the overall exploitation of ocean minerls. As environmental standards evolve for application of seabed resources, new methods for extraction requiring increased costs of development will emerge. These restrictions will develop initially where conflicting uses will be most intense, requiring the greatest planning and regulation.

Dredging systems for coastal exploration will have to be designed so as not to disrupt ocean bottom ecosystems. Environmental restrictions will tend to push exploitation further away from shore. As the need to retain ecological and aesthetic standards intensifies, the enclosed bottom dredge system concept will become more popular, initially being applied in areas of multiple use. Environmental regulations may also catalyze the idea of redepositing ocean bottom residues to land refill sites.

As indicated in the preceding section on energy, the issues rising from competing interests for uses of ocean area in which mineral deposits are located will continue to increase and intensify. This ultimately will lead to the requirement for some form of national policy guidelines regarding sea zones, and permissible uses therein. Political administration and judicial procedures will be developed to provide for the processes needed to resolve these conflicts.

As the general offshore mining industries emerge, there will be a spillover effects in such a manner as to make it further economically feasible to make incremental investments for exploitation which would not otherwise be justified in its own terms. *Within the next two decades, the offshore mineral mining industries will reach the "takeoff point" in terms of their economics of development.* Economics will be used to encompass a demand for minerals, a natural reserve of the minerals, and the economically feasible technologies through which to extract the minerals.

The general capabilities and activities which will be at the forefront of this emerging "subeconomy" will become increasingly evident throughout the remainder of the twentieth century.

The continued evolution of the offshore mining industry will generate a variety of international conflicts. These will be of three basic types:

- Conflicts in rights of development and exploitation of offshore resources
- Conflicts in the "ownership" of economic value or income derived from offshore development
- Conflicts in the relationship between advanced nations' exploitation of the offshore resources and the implications such developments hold for the economies of nations now exporting those resources from land-based reserves

The universal ownership of the oceans' resources, with an effective world organization to manage the development of the resources and the distribution of values derived therefrom, will not become a reality during this century. There

likely will be a variety of treaties and agreements as to the conditions under which exploitation can take place. These will be enforced through adaptations of current international bodies.

As a consequence of the above, *there will be significant political and economic pressures for advanced nations whose economies are resource dependent to develop rapidly offshore mineral mining.* These nations will generally tend to benefit if the oceans remain international. Thus, they will not heartily support universal ownership.

At the same time, *as the oceans currently considered to be international waters, are developed and become important sources of wealth, there will be a drive to extend national control and boundaries, especially economic boundaries, well beyond the 200 mile limits which have emerged recently. These trends will tend to create a variety of conflicts as to rights of access, particularly in those areas involving straits or other channels of relatively narrow passage.* The basic dynamics of these trends are already underway. The entire history of human development reflects that as the economic values of various unclaimed areas rise, the conflicts over rights to the resources also arise. We see no reason to believe the offshore resources will be different, unless some effective international ownership body becomes a reality.

The general tendency will be to extend the economic zones from current boundaries. Nations not bordering the sea could seek a redress of a perceived injustice through various forms of a variety of clandestine antisocial technologies.

The oceans probably will remain open for transport and passage of commercial vessels, but will be continually and increasingly controlled in terms of extraction of resources.

Oil and Natural Gas

See Chapter 4 for forecast on utilization and extraction.

Coal

See Chapter 4 for forecast on utilization and extraction.

Sulfur

The excessive supply of land-based sulfur will encumber further expanded offshore exploration in the immediate short term. However, as new products are developed and as offshore exploration for oil expands an associated increase

in sulfur extraction from the ocean will develop during the last phases of the forecast period. Technological research currently is creating a host of new sulfur based products including applications in the following areas: construction, aggregates, plastics, waterproofing components, substrate for food production. We would anticipate that as these new sulfur products become operationalized, the demand for sulfur as a commodity will increase significantly. As these events emerge, the exploration for offshore oil should be expanding rapidly. Sulfur discovery is closely associated with the exploration for oil. Thus, we would foresee new sulfur pockets inventoried for size and location. The "Frasch" method of extraction, the injection of steam into the sulfur deposit and subsequent flushing of the well site, should continue to be improved and refined for extraction efficiency. Further extraction most likely will be in the Gulf of Mexico, where known sulfur deposits exist.

Hard Rock Mining

The technological innovations developed for extraction of coal (see Chapter 4 on energy) will create the technological base to extract hard rock mineral and selective mining will occur. The extent to which hard rock mining occurs will be a function of the commodity market conditions at a given time period; however, lead, iron, and manganese are critical metals to the national economy in which a higher probability for extraction exists. Technological adaptations from offshore coal and oil extraction may include underwater mine sitings with underwater living quarters and offshore refinement or processing facilities.

Sand and Gravel

The demand for sand and gravel as key components in construction aggregates will accelerate and the cost of utilizing land-based deposits also will increase. The mining of offshore sand and gravel is a demonstrated technology with applications throughout the world, and is an expanding industry within the U.S. The exploitation of land-based sand and gravel will become increasingly unattractive because of depletion of already known deposits, and because of the high cost of transportation. Offshore exploitation should expand most frequently in major metropolitan areas where the cost of obtaining land based aggregates competes with those derived from the sea.

As the activity expands, rapid technological adaptations and advancements will occur for offshore mining techniques. Environmental concern over disruptions of the ocean bottom and the visibility of traditional dredging operations

will spur increased utilization of the semisubmersible or submersible dredge. We anticipate the extracted material will be transported from an underwater dredge, controlled remotely or manned, via pipeline directly to cement processing plants located on shore or floating immediately offshore.

Limestone and Shell

Offshore mining of limestone and shell will be coupled with the extraction of sand and gravel; thus, as stated in the previous paragraphs, a rapid emergence of this activity is anticipated. The extraction of limestone and shell is associated intimately with the removal of sand and gravel in that these materials often are located in the same geophysical locations and utilize the same operational systems for extraction. Because limestone can be used as a base for fertilizers, extraction from the Gulf of Mexico where there is a large agricultural demand will be for these purposes, whereas northern Atlantic extraction primarily will be to generate construction aggregates, the other major end use.

Placers

The demand for the minerals comprising the placer category, the heavy minerals, will become accelerated as land-based supplies become exhausted and as importation prices escalate. The metals entitled placers are critical to the national economy and are heavily utilized by industry. As the offshore mining industry expands into the areas of sand and gravel, limestone and shell, we would anticipate technological spinoffs which enhance the likelihood for placer extraction. The stratified nature of placer deposits will require an increasingly sophisticated dredge head for underwater removal of these minerals. The submersible dredge, which promised greater control in extraction will facilitate the development of placed mining. The underwater exploitation of placers will also be promoted by national efforts to improve the balance of trade, and to deter potential cartels from developing. Many of the placers currently imported are from foreign nations, some of which can be viewed strategically as unsafe.

Manganese Nodules

The international competition for exploitation and the associated high value of the essential components within the nodules will foster a rapid acceleration in worldwide extraction. The mining of the nodules has been demonstrated technologically and economic analyses indicate that this resource could be extracted in a cost-effective manner. As stated previously, we do not foresee the development of universal ownership of the world's mineral resources, rather

potential conflicts over rights of claims will emerge. *Technological advances in extraction methods will facilitate the rate and depth at which the mining for nodules occurs.* Improvements in hydraulic pumps to increase suction capabilities and refinements in the bucket line system are anticipated. Initial extraction should occur in the Pacific ocean since the deposit concentration of the nodules is greater than in the Atlantic ocean.

Red Clay/Ooze

Given the present conditions, land-based supply of minerals contained within red clay and the projected high cost of extraction of this material, this activity is not expected to emerge in any sizable fashion during the forecast period. Nonetheless, it is conceivable that some small-scale operation could be initiated prior to the year 2000. The geographical locales will further encumber exploitation.

<u>Phosphorite</u>

The abundance of land-based supplies of phosphorite will deter extraction of this mineral from the ocean during the early phases of the forecast period; however, by the year 2000 some offshore exploitation of phosphorite can be anticipated. The most widely applied use of phosphorite is in the production of fertilizers, of which the U.S. is the largest producer and exporter. We would anticipate that the demand for fertilizers worldwide and nationally will foster the continued extraction of phosphorite from the land. However, the extraction methods that are utilized for sand and gravel, will have direct application for the removal of phosphorite. By the year 2000, as land-based supplies begin to become seriously depleted, we would anticipate that a shift from land to ocean extraction of phosphorite will occur.

<u>Metaliferous Muds</u>

The high concentration of valuable minerals embedded in metaliferous muds, in conjunction with the emerging technologies for deep sea mining, will enable the extraction of these muds to be accomplished in some exploratory phase by the year 2000. Geologist, have been aware of the potential resources that lay immediately below the metaliferous muds. However, extraction seemed unrealistic because of a large technology gap. The technologies that are being developed for deep sea oil extraction, and nodule mining will have spinoff application for the mining metaliferous muds. From a resource perspective, many of the valuable minerals within this geophysical region will be in short supply by the year 2000. These two factors, the technological know-how and the resource demand, should promote

some international exploitation of metaliferous muds. The most likely region for initial extraction may be the Red Sea. This area has had initial inventory completed on mineral supply. Other areas of operations will be in regions where tectonic plates are joined, such as oceanic ridges in the Atlantic and Pacific oceans.

Chemical Extraction

The removal of minerals such as salt, bromine, and magnesium from the ocean will continue to occur throughout the forecast period. However, these application will not shift from land-based production facilities to ocean-sited production platforms or any other ocean operational milieu. Thus, their impact on the underwater environment of which we are primarily concerned will be of little significance.

Desalination/Iceberg Towing

The demand for fresh water will increase substantially in the next twenty years due to the changing nature of world climatological patterns, the expanding world population and the continued need for agricultural irrigation. *These events will spur new investigations to harness or produce water and, subsequently, desalination plants will expand in size and number and some type of iceberg towing applications will occur.* In both of these situations the U.S. need for application is less than those of countries which have predominately arid climates. Thus, many of the mideast nations utilize desalination plants as a supply of water and currently are finishing the initial engineering concepts for iceberg towing. The adaptation of desalination plants most likely will occur in regions of the U.S. which are subject to drought conditions, yet traditionally are in an agricultural area of production. Southern California fits this description and is a high probability candidate for a U.S. desalination plant.

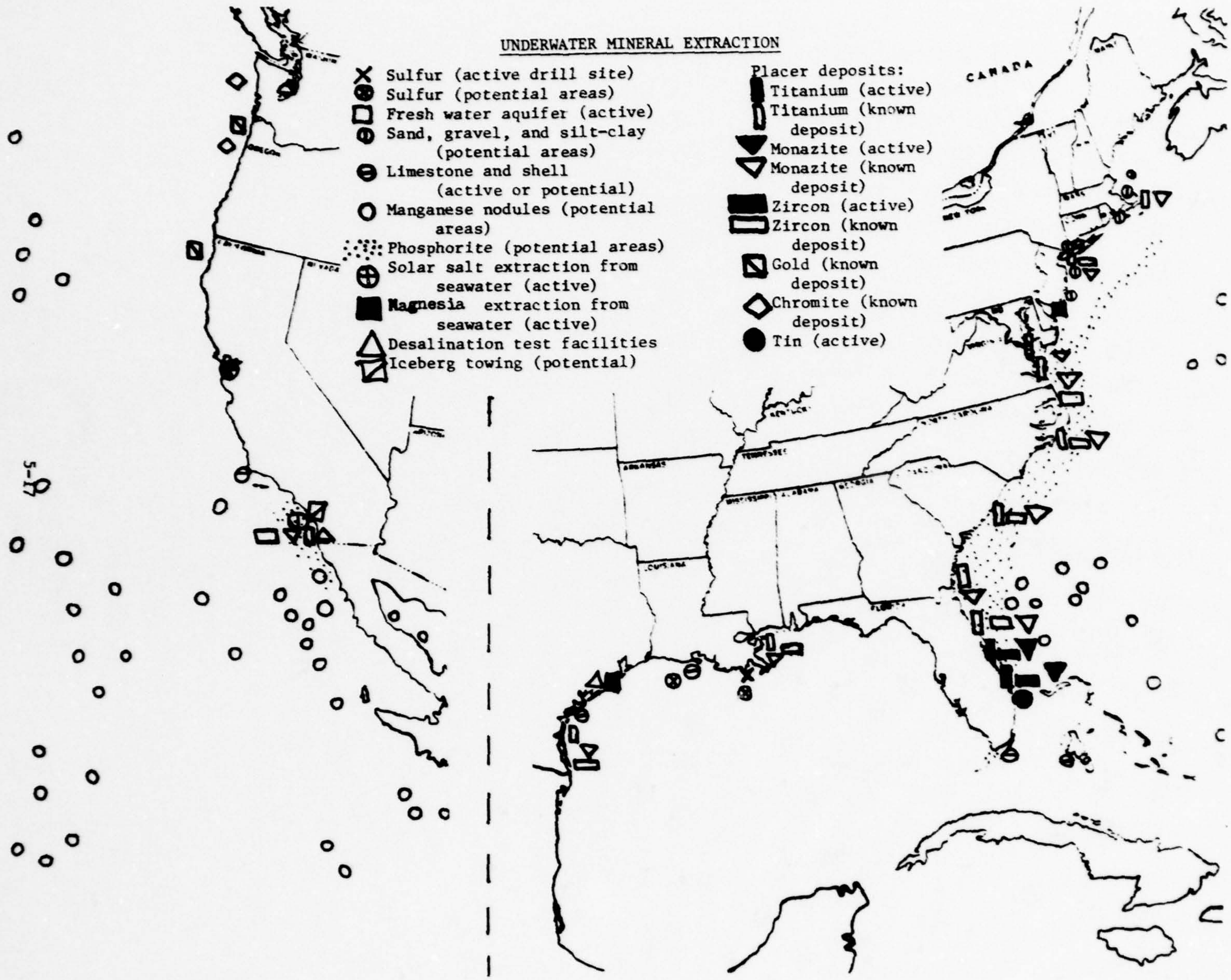
FIGURE 5-5: TAILORED VIGNETTE - MINERALS

FORECASTED DEVELOPMENTS	PROBABILITY/TIMING 1981-85	1986-92	1993-2000
INTENSE INDUSTRIAL ECONOMIC GROWTH REMAINS PREFERENTIAL CHOICE OF SOCIETY	H	H	H
EXTRACTION OF OCEAN MINERALS BECOMES IMPORTANT ASPECT OF NATIONAL POLICY AND PRIORITY	G	H	H
MOTIVATING FACTORS FOR OFFSHORE EXTRACTION INCLUDE:			
• TECHNOLOGICAL DEVELOPMENTS FROM OIL AND GAS EXTRACTION	G	G	H
• DEPLETION OF LAND BASED SUPPLIES	L	G	H
• MINERALS VIEWED AS STRATEGICALLY SIGNIFICANT	L	G	G
COST DISADVANTAGES ASSOCIATED WITH OFFSHORE MINING WILL BE NEUTRALIZED BY:			
• IMPROVED DISCOVERY TECHNIQUES	G	H	H
• GOVERNMENT ECONOMIC INCENTIVES	G	H	G
• TRANSPORTATION COSTS OF LAND BASED MINERALS	H	G	L
FAVORABLE SOCIO/POLITICAL CLIMATE FOR UNDERWATER EXPLORATION REMAINS	G	H	H
ENVIRONMENTAL ISSUES WILL ESCALATE IN NATIONAL IMPORTANCE BUT WILL NOT SERIOUSLY IMPEDE EXTRACTION			
• IMPROVED DREDGING DESIGN IMPACT LESS ON UNDERWATER ENVIRONMENT	G	H	H
• NEED FOR NATIONAL POLICY AND GUIDELINES FOR SEA USE AND SEA ZONES REINFORCED	G	H	G
UNIVERSAL OWNERSHIP OF OCEANS'RESOURCES WITH AN EFFECTIVE WORLD MANAGEMENT AND DISTRIBUTION SYSTEM BECOMES OPERATIONAL	M	M	M
EXTENSION OF NATIONAL BOUNDARIES BEYOND THE 200 MILE LIMIT REALIZED SO THAT NATIONS CAN EXTEND THEIR ECONOMIC RESOURCES	M	G	G
SEE CHAPTER 4 FOR TAILORED VIGNETTE ON OIL AND NATURAL GAS, AND COAL EXTRACTION			
GULF COASTAL STATES EXPAND OFFSHORE SULFUR PRODUCTION BECAUSE:	L	L	G
• NEW PRODUCTION TECHNOLOGIES	L	L	G
• LOCAL NEED FOR AGRICULTURAL FERTILIZERS	L	G	G
• OIL AND GAS PRODUCTION IN AREA HAS ASSOCIATED SULFUR DEPOSITS WHICH HAVE BEEN LOCATED AND INVENTORIED	L	G	G
HARD ROCK MINING BECOMES OPERATIONALIZED USING COAL EXTRACTION TECHNIQUES	L	L	G
COMMODITY MARKET CONDITIONS DETERMINE TYPE OF MINERAL EXTRACTED	L	G	G
CONTINUED EXPLOITATION IN COASTAL WATERS TO MINE SAND AND GRAVEL, AND LIMESTONE AND SHELL	G	H	H
CONVENTIONAL SURFACE SUCTION OR CUTTERHEAD DREDGES:			
• FIND CONTINUAL USE	H	G	G
• OPERATE IN MOST OCEAN ENVIRONMENTS	G	G	G
• PUMP DIRECTLY INTO LAND BASE PLANTS FOR MANUFACTURE OF FERTILIZERS OR CONSTRUCTION MATERIALS	L	G	H

(CONTINUED)

FIGURE 5-5: TAILORED VIGNETTE - MINERALS (CONTINUED)

FORECASTED DEVELOPMENTS	PROBABILITY/TIMING 1981-85	1986-92	1993-2000
PROTECTION OF LIVING REEFS AND SURROUNDING ECOSYSTEMS, ACHIEVED BY DREDGING HEADS WHICH OPERATE IN SPECIFIC AREAS AND DO NOT REDEPOSIT IMPURITIES ON OCEAN BOTTOM	G	G	H
INCREASED UTILIZATION OF SUBMERSIBLE DREDGES FOR IMMEDIATE OFFSHORE EXTRACTION OF SAND, GRAVEL, LIMESTONE, AND SHELL; SATISFIES REGULATORY AND ENVIRONMENTAL CONCERN OVER DISRUPTIONS OF UNDERWATER ENVIRONMENT AND BECOMES ECONOMICALLY ADVANTAGEOUS OVER SURFACE DREDGES	G	H	H
PLACER EXTRACTION ADOPTS TECHNOLOGIES UTILIZED FOR OFFSHORE EXTRACTION OF SAND AND GRAVEL AND BECOMES ACTIVELY PURSUED	L	G	G
NODULE EXTRACTION DEVELOPS RAPIDLY FOSTERED BY INTERNATIONAL COMPETITION AND HIGH VALUE OF MINERALS	G	H	H
TECHNOLOGIES UTILIZATION FOR EXTRACTION OF NODULES INCLUDE:			
• BUCKET LINE SYSTEMS	G	H	H
• HYDRAULIC SUCTION SYSTEMS	H	H	H
MINING NODULES BECOMES IMPORTANT THOUGH ONLY PARTIAL SOURCE OF NATIONAL AND INTERNATIONAL MINERAL SUPPLY	L	L	G
EXTRACTION OF RED CLAY/OOZE EXPERIMENTALLY DEVELOPED	L	G	G
OCEAN EXTRACTION SIGNIFICANTLY SUPPLEMENTS LAND-BASED SUPPLIES OF PHOSPHORITES	L	L	L
INHERENT HIGH VALUE OF MINERAL DEPOSITS FOUND WITHIN METALIFEROUS MUDS ACTIVATES PURSUIT OF THIS RESOURCE, UTILIZING TECHNOLOGIES APPLIED IN OIL AND NATURAL GAS PRODUCTION AND DEEP SEA MINING	L	G	G
CHEMICAL EXTRACTION OF MINERALS SUCH AS SALT, BROMINE, AND MAGNESIUM WILL CONTINUE IN LAND-BASED FACILITIES ADJACENT TO THE OCEAN	H	H	H
SALINATION PROJECTS EXPAND IN AREAS OF EXTREME ARID CLIMATES	H	H	H
U.S. DEVELOPS ECONOMIC AND FEASIBILITY STUDIES FOR DEMONSTRATION DESALINATION PROJECTS WITHIN THIS COUNTRY	L	G	G
ACTUAL DEVELOPMENT OF SALINATION AS MAJOR SUPPLIER OF WATER IN AREAS SUCH AS SOUTHERN CALIFORNIA	L	L	G
ICEBERG TOWING ACTIVELY PURSUED BY NATIONS WITH YEAR ROUND ARID CLIMATES	G	G	G


UNDERWATER MINERAL EXTRACTION
Sulfur (active drill site)
Sulfur (potential areas)
Fresh water aquifer (active)
Sand, gravel, and silt-clay (potential areas)
Limestone and shell (active or potential)
Manganese nodules (potential areas)
Phosphorite (potential areas)
Solar salt extraction from seawater (active)
Magnesia extraction from seawater (active)
Desalination test facilities
Iceberg towing (potential)
Placer deposits:
Titanium (active)
Titanium (known deposit)
Monazite (active)
Monazite (known deposit)
Zircon (active)
Zircon (known deposit)
Gold (known deposit)
Chromite (known deposit)
Tin (active)
CANADA

CHAPTER 6: "AGRICULTURAL PRODUCTION"

DEFINITION

It may appear strange to think of an underwater agricultural system. The term "agricultural" however, is useful because its connotation is broader than "aquaculture," a term which has come into general usage to mean a relatively limited range of activities within the overall concept of marine "Agricultural Production." Underwater "agricultural production" includes the following:

- All activities associated with growth and harvesting of fish and shellfish for commercial or recreational purposes
- All activities associated with the growth and harvesting of all other marine organisms
- All activities associated with the growth and harvesting of marine plants

BACKGROUND

Man has used various forms of marine animal and plant life for centuries. A major component of human history involves developments which have been directed at how marine resources could be more effectively captured and employed. Examples include the developments in fishing techniques which have advanced from a quick eye and hand, to a spear, to nets, to various forms of spotting, and to attraction devices such as sonic instrumentation.

The recent adoption of the 200 mile limit is a current example of the growing importance of marine agricultural activities. Emerging concepts such as those of aquaculture, ocean farming and biomass energy from kelp are futher testaments to the importance of the agricultural role of the marine environment.

Our forecast of future underwater activities related to this marine agricultural role is developed against a general backdrop which includes the following major trend lines or developmental dynamics:

- Fishing techniques will improve, but there will be more fishing industry competition between nations.
- Offshore agricultural resources, including plants, will become a more important component of the world economy and of the U.S. economy.

- These developments will both stimulate and be stimulated by an active and dynamic series of technological advances and innovations.
- The ultimate direction of the agricultural activities is movement from a "hunt and catch" type of system toward a managed, cultivate and harvest type of system. A reasonable analogy is found in the history of land agriculture, which moved from the hunting era into the cultivation/management era through the advent of the agricultural revolution. This land-based agricultural revolution began centuries ago and continues today. The same is true of the marine based agricultural revolution, although it has not been so articulated by historians nor has it been so pronounced in its visibility and impact upon living styles and patterns.

FUNCTIONAL SYSTEM

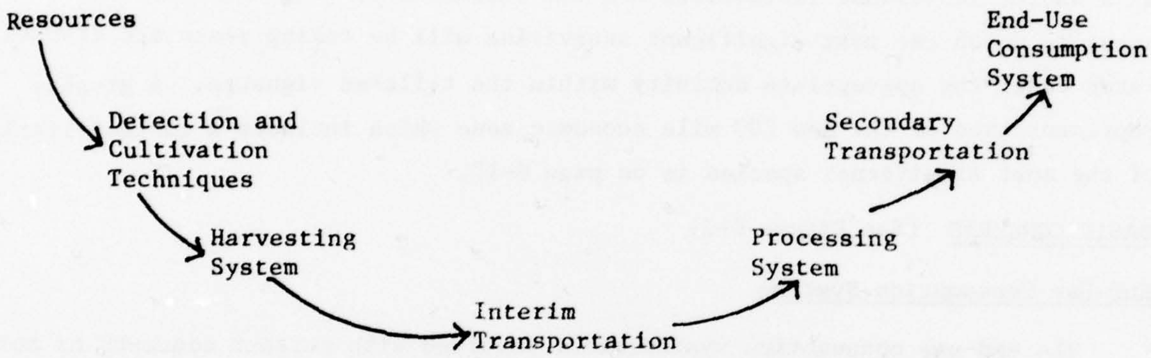
The overall underwater agricultural system contains the following basic components:

- End Use Consumption Systems: the social and economic systems which levy a demand for marine agriculture.
- Marine Agricultural Resources/Potential: the entire range of offshore agricultural commodities either naturally occuring, or those which can be artificially incorporated into the marine environment.
- Detection and Cultivation Techniques: the procedures used to locate harvestable resources which are naturally present or the procedure used to observe the placement and subsequent maturation of artificially placed agricultural resources.
- Catching and Harvesting: the processes used to catch or harvest the agricultural resources.
- Interim Transportation: the in-between mode of transport from point of harvesting to processing.
- Processing: the procedures employed to refine the agricultural resources into "useable" eatable condition or into an appropriate form for additional processing. Some processing facilities are currently located offshore, such as those associated with the "floating fish factory."
- Secondary Transportation: in some instances agricultural resources may require secondary transportation even within the marine environment. The first type, interim transportation, may be a collection procedure to get large

quantities to move to land. Secondary transport would be the movement of the larger mass to land. Another example may entail interim transportation to an offshore processing facility which then requires secondary transportation for its "finished goods" to the next stage in the overall material processing and flow.

These basic functional components of the operational system are outlined in Figure 6-1.

FIGURE 6-1: FUNCTIONAL COMPONENTS FOR AGRICULTURAL PRODUCTION



GEOPHYSICAL PERSPECTIVES

Agricultural resources have highly sensitive requirements for conditions conducive to their growth and development. Factors such as temperature, depth, light, motion, and presence of required nutrients will determine where various aspects of underwater agricultural activities can take place.

Unlike the cases with mining and energy production, agricultural production does lend itself more to some locational flexibility which can be affected by human intervention. For example, recent concepts of "ecological engineering" envision deliberately designed interventions to create the needed conditions in areas not so endowed with them by nature. Floating nuclear plants could significantly raise the temperature of water within their proximity, suggesting increased productivity of agricultural plant and animal life. Implantation of nutrients could affect where fish may cluster, and could also significantly increase the productivity of certain areas of the marine environment.

In this sense, as a generalized class of activities, underwater agricultural pursuits can occur within virtually all waters within the territorial limits of the United States.

Some analysts have pointed out that the Northern Hemisphere is more fished than are the waters of the Southern hemisphere even though the potential productivity of the Southern hemisphere is equal or maybe superior. It is generally anticipated that significant fishing and marine agricultural activities will increase within the Southern as well as the Northern hemispheres.

Given these generalized geophysical perspectives in terms of the activities as a whole, individual limitations are not discussed in this chapter. The areas in which the most significant activities will be taking place are discussed later under the appropriate activity within the tailored vignette. A graphic representation of the new 200 mile economic zone which includes a current listing of the most significant species is on page 6-17.

BASIC CONCEPTS (See Figure 6-2)

End-Use Consumption Systems

The end-use consumption systems most involved with current concepts of marine agriculture are:

- Food systems: human and animal
- Fertilizers and other nutrients for plant growth
- Energy systems which can convert biomass
- Other systems which can use marine plant or animal life.

Food Systems

One of the most historically stable aspects of the overall marine economy has been its contribution to human and animal food chains. These contributions have been limited to the hunting and catching of fish and shellfish, with a few highly selective additions such as squid into the gourmet food lines. Fish are also a rich source of nutrients for animal feeds. In this capacity, seafoods must compete with land-based foods and nutrients. There are a variety of proposals for land-based agricultural productivity increases which could have significant effect upon the forecasted demands for food materials from the sea.

These concepts include employment of fermentation systems as a means of creating high quality protein from lower quality plant life for a reduced cost. New crops

FIGURE 6-2: TAILORED FRAMEWORK: UNDERWATER ACTIVITIES RELATED TO AGRICULTURAL PRODUCTION

	Key Driving Forces	Key Barriers	Obviating Factors
End Use Consumption Systems Food systems - human and animal Fertilizers Energy systems Other systems Offshore "Agricultural" Resources Fish and shellfish - natural - managed/natural - implanted/cultivated Other marine organisms - natural - managed/natural - implanted/cultivated Plants - natural - managed/natural - implanted/cultivated Detection and "Cultivation" Fish and shellfish Other marine organisms Plants Catching and Harvesting Techniques Nets Electronic entrappment Chemical barriers Harvested Underwater manipulators/collectors Interim Transportation Surface vessels Submersibles Pipelines Cables Other Processing On land Offshore Secondary Transportation Fish and shellfish Other marine organisms Plants	Enactment of 200-mile zone provides for regulation of foreign vessels Development of sensing methods which provide specific information as to catch size and location Continued need for protein sources Health appeal of fish Maintenance of traditional industry International competition for utilization of marine resources. Concepts of "total" marine farms Management concepts for fish regulation, stock augmentation, marine organisms and marine plant growth	Present harvesting techniques and gear that are antiquated Present processing technology Quality of fresh fish product--refrigeration capabilities of present fleet are very poor Labor supply has been decreasing State and local regulatory decisions Competitive uses in some areas Lack of trained personnel Marketing practices	Replacement of ocean resources with complete reliance on land derived products Substitute protein and other food sources developed/utilized

and productivity/processing improvements for land-based foods are another alternative source, offering the potential of eliminating the need for seafoods. But perhaps the most significant substitute is the proposition of land-based aquacultural systems in tanks or other controlled inland bodies of water such as ponds or lakes.

Fertilizers

Demands for some marine and plant life relate to use in fertilizers. To whatever degree organic fertilization becomes a replacement or a preference for chemical fertilizer, the demands for marine agricultural products to go into the fertilizer streams could be substantially enhanced.

Energy Systems

The energy problems have stimulated a number of concepts in which biomass may be converted to various forms more suitable for energy use, or in which biomass may be burned directly as a fuel. In either case, the potential for large sources of biomass energy has been clearly defined to rest within the underwater environment. These concepts were discussed in Chapter 4 on Energy.

Other Systems

A variety of other systems use plant and animal products from the sea. These include pharmaceuticals, chemicals of various types, sponges, whale oil and many others. Although they are not typically as high volume in nature as are fishing, they are nevertheless a significant and growing dimension of the underwater agricultural resource markets.

Offshore "Agricultural" Resources

Offshore agricultural resources can have three basic origins:

- The resources which are a result of nature
- The resources which are a result of nature and human management
- The resources which are a result of human implantation and cultivation

The resources from nature might be characterized as a hunt and harvest concept, the traditional manner of gathering plants and animals. This initial concept included any improved methods of detection which locate plants and animals,

the methods of harvest, and finally the transportation of these resources to the next point of processing.

Recently there has emerged intervention techniques which further develop some controlled management methods. Pollution controls which protect fish beds and the surrounding ecosystems is one such example. Another is controls to preclude over-harvesting. Augmentation of fish stocks by utilizing fish hatcheries for breeding of juveniles is another management system. These concepts are now being further developed to consider ways in which nutrients and other geophysical features of the "native waters" or territories might be enhanced as a means of increasing the productivity of the otherwise "wild and natural" ecology.

Finally, in recent years a rapid growth of the the number of ideas whereby man, through effective management and intervention, might cause various forms of plant and animal life to grow and thrive in natural environments has been attempted. This concept includes the "controlled fisheries" and the cultivation of marine species in environments, in tanks, or in confined "ocean farms." The implantation of plants such as kelp for the purpose of biomass energy is an example of highly managed intervention.

All of these three basic conceptual categories are overlapping with one another. It is helpful to analyze the probable future developments from this categorization.

Present research efforts include:

- Efforts to improve disease prevention and other means of protecting the desirable species
- Hatchery design
- Genetic improvements and egg supplies.

At the present time, aquaculture is conceived of in a relatively narrow sense which would primarily restrict it to the second category. As future developments unfold, the boundaries and perspectives will likely broaden significantly.

Of particular note is the possibility discussed in Chapter 8 where there is a brief discussion of the concept of managing certain forms of waste materials to serve as nutrients to plant and animal life.

Detection

The variety of methods employed to locate fish or other marine species range from the visual observation of individual fishermen to the portrayal of a school of fish detected from a satellite. In recent years, most new fishing vessels are equipped with some form of sonar, radar, or other direction finder system. The increasing reliance upon electronic or other wave generation detection systems should accelerate throughout the forecast period. New technologies that appear to be emerging include:

1) Satellites' expanding sophistication, incorporating laser and infrared methods for spotting moving fish
2) Underwater systems which accurately portray the location and size of fish by acoustically sensing systems
3) Unmanned passive systems such as buoys which record and emit the location of marine species

The cultivation of marine plants below the ocean's surface will require a close monitoring and observation system to insure that the plants are lodged properly onto some type of underwater substrate and to record the growth progress of the plant. Mechanisms to achieve these ends include the establishment of a television camera system which transmitts either to a vessel or land facility pictures of the plants. An alternative approach will be to utilize manned submersibles or divers for direct human observation. This last technique is also applicable to the cultivation of shellfish.

The utilization of marine species to detect the presence of another animal is typified by the dolphin/tuna relationship. This concept potential has other applied usages in situations where different species share the same migratory behavior or in fact co-exist in some unique biological relationships. As these types of biological phenomena are detected their applied significance to agricultural production systems will be ascertained.

The harvesting of agricultural products, specifically fish, is a function of the vessel employed and the trapping system utilized, often typified by some form of netting system. The U.S. fishing industry seriously lags behind other advanced nations such as Japan and Russia in adopting current state-of-the-art technologies, and in planning for future innovations. Restrictive state and federal laws have seriously inhibited the purchasing of new equipment, the reconditioning of old vessels and the utilization of specific harvesting systems including nets.

The U.S. fishing fleet has often been described as aging and antiquated. A representative ship would be 20 years old, individually owned and operated near shore. This constrasts dramatically with many foreign fishing vessels which not only are larger but have greater catch and storage capability. The ultimate extreme of fishing sophistication is represented by the floating factory or open stern trawler concept. In this case, the vessel not only harvests the fish but has storage, processing, and in some, packaging facilities as operational components.

Vessel maneuverability and durability potentially can be enhanced by the adaptation of new lightweight, durable metals developed and utilized for space vehicles and satellites. Automatic computer control systems coupled with on board detection systems offer the prospect for improving catch time by reducing the time required normally for the "hunt" phase of the fishing catch.

Irrespective of boat size, the catching techniques for most ships with some variation, is a netting system. Net design and use is often a function of the type of fish that is being pursued. Advancements in netting systems that appear rapidly developing include:

1) Expanding net size and changing shape to a funnel so that migrating species are "corraled" into an enclosed area

2) Automatic netting systems which are remotely controlled and are activated only when a sizable catch is present

3) Utilization of unmanned submersibles to rapidly close a netting system.

The above methods share the common attribute that they are systems which curtail the reliance on human involvement. Thus the analog to land agriculture can be further extended: as efficiency improves the depeandance on human labor diminishes.

These netting mechanisms have analogous application for the entrappment of species such as octopus, sponges or squids. In general, these trapping mechanisms for underutilized species have not been developed to the same technicological state as those for fish, which reflects the fact that their economic significance is less.

Non-netting systems for the entrappment of fish include the utilization of electronic stunning and chemical barriers. For the first system, an electronic transmission through the water momentarily immobilizes the fish and they float to the surface where they are gathered. In the second system, a chemical is released either from a stationary site (buoy or platform) or from the vessel which

creates an invisible screen in which the fish cannot penetrate. The fish are then netted on board the vessel. The chemical barrier procedures may also be applied to the artificial cultivation of fish. In these circumstances the chemicals create an underwater fence, which the fish will not penetrate.

The current mechanisms to harvest marine plants include the use of harvesting vessels which have built-in reapers and shearers to cut and collect the plant, and the use of humans (marine farmers) who pick the marine plants by hand. Current investigations envision the development of underwater manipulators and cutters that could be operated by remote control or by underwater divers.

Interim Transportation

Some of the concepts applicable to this section were previously introduced under catching mechanisms. (Netting could be a mode of interim transport.) Advancing technologies that apply to all forms of marine agricultural production include:

1) Pipelines--Offer the potential to gather marine species via a vacuum cleaner approach. In this situation, fish which may be confined to a particular locale by chemical barriers could literally be swept up out of the water onto a vessel.

2) Submersibles--could be used in collecting marine plants or in closing net systems. For underwater cultivation systems they offer the further potential of actually being the harvesting vehicle. The submersible simply replaces the fishing vessel as the conventional mode of interim transport.

3) Surface vessels--Have been the most common mode of transport for marine species and technological developments should simply improve their efficiency at achieving this task. The developments of specialized vessels such as refrigeration ships to act as a functional mediator in the agricultural production cycle offers new possibilities.

Processing Systems

Two major concepts exist for processing marine species and they are simply a function of locale, land vs. on-vessel. On-vessel processing presently is represented by the floating factory concept. The functional attributes of such a system include the ability to harvest, process and preserve marine species (mostly fish) for long periods of time. This capability allows vessels to travel further from their home port and to increase their catch size. The adaptation of this concept to other marine organisms and marine plants seems feasible.

On-land processing systems have sought to eliminate wastefulness which normally describes their operations. Technological advancements are developing in the following areas:

1) Automatic shuckers to process mollusks
2) Deboners and flesh separators which automatically fillet fish
3) Irradiation pasteurization techniques
4) Automatic shrimp peelers
5) New product development

As untraditional marine species become more utilized there exists a subsequent push for new product development. Krill meal and octopus fillet are two types of this innovation.

TAILORED VIGNETTE (See Figure 6-3)

In current forecasting literature, much attention is paid to the proposition that the world food shortage will lead to extensive development of the marine agriculture as a means of protein and food production. Some analysts conceive that the situation will be so critical that ocean plants, such as kelp, will become as important to the world food supply system as are such traditional commodities as wheat today. Such visionaries foresee rapidly growing ocean farms of all types. There is little doubt that these concepts are within reach technologically. However, we do not believe they will emerge with the intensity and scale which is often envisioned. At the other extreme is the view that the marine agricultural system is already reaching its leveling off point; at least so far as the U.S. territorial waters are concerned. Based primarily upon fishing, which is the largest segment of this industry, these views point out that current demands are already placing a drain upon fish populations. Overfishing is a problem now and will become a greater problem as the fishing techniques and demand increases. Prices for fish and fish products are climbing rapidly, reflecting at least partially their growing relative scarcity. Our own view is that this is a far too pessimistic perspective. The ultimate pattern which will emerge will be somewhere between these two extremes and will have the following basic characteristics.

Agricultural production within the marine economy will accelerate throughout the forecast period, fostered by the traditional national perspective of agrarianism. The cultivation of food stuffs as originally manifested by the exploitation of the lands has not only satisfied the obvious physiological needs of man, but has also been construed as a viable part of our national heritage. Similarly the

exploitation of ocean resources offers the social constructs upon which national agrarian needs are fulfilled. From this perspective, marine agricultural production will continue to remain an industry that is viewed as significant and important, and one which should remain viable. However, as expansion and refinement of agricultural production methods on land has demonstrated graphically, what historically has been a labor intensive industry, typified by the small scale individual worker, need not remain. In fact as "agribusiness" has been developed in the recent past, its marine counterpart "aquabusiness," the cultivation and exploitation of marine products, should emerge during the forecast period. This trend portends a decreasing reliance upon the small scale individually owned and operated fishing boat to a shift exemplified by high efficiency, large scale harvesting methods.

Substitute protein sources will be developed within the duration of the forecast period but these alternatives will not curtail consumer interest and demand for the conventional protein staples of beef, poultry, and fish. Efforts to develop new protein sources generally have as a common objective the creation of protein boosters. Hence, protein alternatives that will be formulated will be to fortify or supplement conventional proteins such as the general purposes soy is utilized. Most projections for the human consumption of fish and shellfish indicate a long term increasing demand. Part of this trend reflects medical evidence that has verified fish proteins are without the high fats and cholesterol of beef proteins. Furthermore, beef conversion mechanisms of plant protein is very inefficient. Other current trends favor the expanded reliance upon marine based proteins such as kelp, squid, or krill. As marine resources supply the demand for food, agricultural production will incorporate underutilized species for new product development. In this perspective, fish which have been harvested for animal feed purposes will be utilized by refinement techniques to fit into the human food chain. Also, marine plants which thus far have had demonstrated success as food stabilizers will find increased functional capabilities in new food products and pharmaceuticals.

Present harvesting techniques and processing hardware encumber full exploitation of the total fish supply. Within the immediate short term many vessels that comprise the U. S. fishing industry will have to be reconditioned or replaced, which will accentuate the economic insufficiency of the present harvesting system. Major changes in the composition of the U.S. fishing industry will have to take place to make the industry again viable. In the

immediate future, in order to improve the economics of the marine harvest, existing ships will be reconditioned with new refrigeration equipment; new ships, larger in size than those presently being used, will be constructed; and some netting systems, now restricted, will be utilized. These changes will allow for an increased catch. *Once the fishing industry emerges from its present state of stagnation, worldwide exploration in international waters, utilizing the concepts of the floating factory and open stern trawler, will be a further extension of this revitalization.*

As mandated by the establishment of a new 200 mile zone, new management concepts and data collection systems will be formulated to obtain an integrated view of all fisheries of the U.S. and to determine the optimum yield of each fish species. Previous attempts to manage fisheries have been done solely in a biological perspective, without evaluation of ecological, social, or economic factors. These key variables will be incorporated into future management decisions on fishing. Management techniques will be greatly enhanced by the utilization of new sensing mechanisms, which not only locate and track fish but will isolate specific species. As a direct result of these sensing techniques, regional allotments of certain species of fish will be required to protect against stock depletion.

The utilization of offshore water for a variety of activities will significantly alter the scope of agricultural production. Competition for water space will be most keen in the immediate coastal areas. These waters will be affected from divergent sources, including industrial waste and municipal runoffs, recreational activities, and dredging. We would anticipate that aquacultural activities and the conventional shellfish industry could be affected adversely and seriously by these other activities. Because many of the coastal activities that will be developing will be disruptive to the integrity of the natural ecosystems, the purity of the water and, in some cases, the actual physical ocean bottom, marine aquaculture will be impeded seriously from developing. Many aquacultural systems require sustained stability in the surrounding water environment. Aquacultural projects will alter some of the present underlying research foundations. In this perspective, for example, the heat discharged from an industrial facility will not be viewed as a potential disruptive threat for growth, but will be incorporated into the initial design of the aquaculture project as a heat source. Therefore, we anticipate,

after an initial disappointing phase in aquacultural exploitation, that successful implementation will be realized as a component of an integrated system with either industrial waste, power plants, or offshore energy systems.

In the extreme, these developments will lead specifically to zoned fish farms, (other marine species) in which the population of a certain stock is concentrated in a small easily managed area and readily harvested. The con-concepts utilized for regional enforcement of the 200-mile economic zone will have direct application to the successful fruition of the concept of an integrated marine farm.

The growth of recreational fishing will compete with the traditional fishing industry for the natural resources of the oceans. The ensuing conflict will be resolved by the establishment of zones which permit only recreational fishermen to utilize the area. Recreational fishing in the underwater is traditionally represented by the activities of the fishermen who pursue their catch either from land (jetties or beach fronts), small 2-6 man boats or sport boats typified by the party or charter boat. The most common forms of equipment used for recreational fishing, which also includes the pursuit of shellfish, are the conventional hook and line, and underwater traps and nets. This equipment should continue to be the main means of catching during the forecast period. Recreational fishing will increasingly utilize detection systems which in turn will increase their efficiency and exacerbate the conflict with the commercial interests. The sea zone management concepts which will help to establish marine farms will be applied to the formation of recreational fishing zones. These designated areas will occur in coastal regions which seem amenable to artificial augmentation. Thus, as indicated previously, carefully managed injection will increase marine species yield and will not encumber traditional fishing interest.

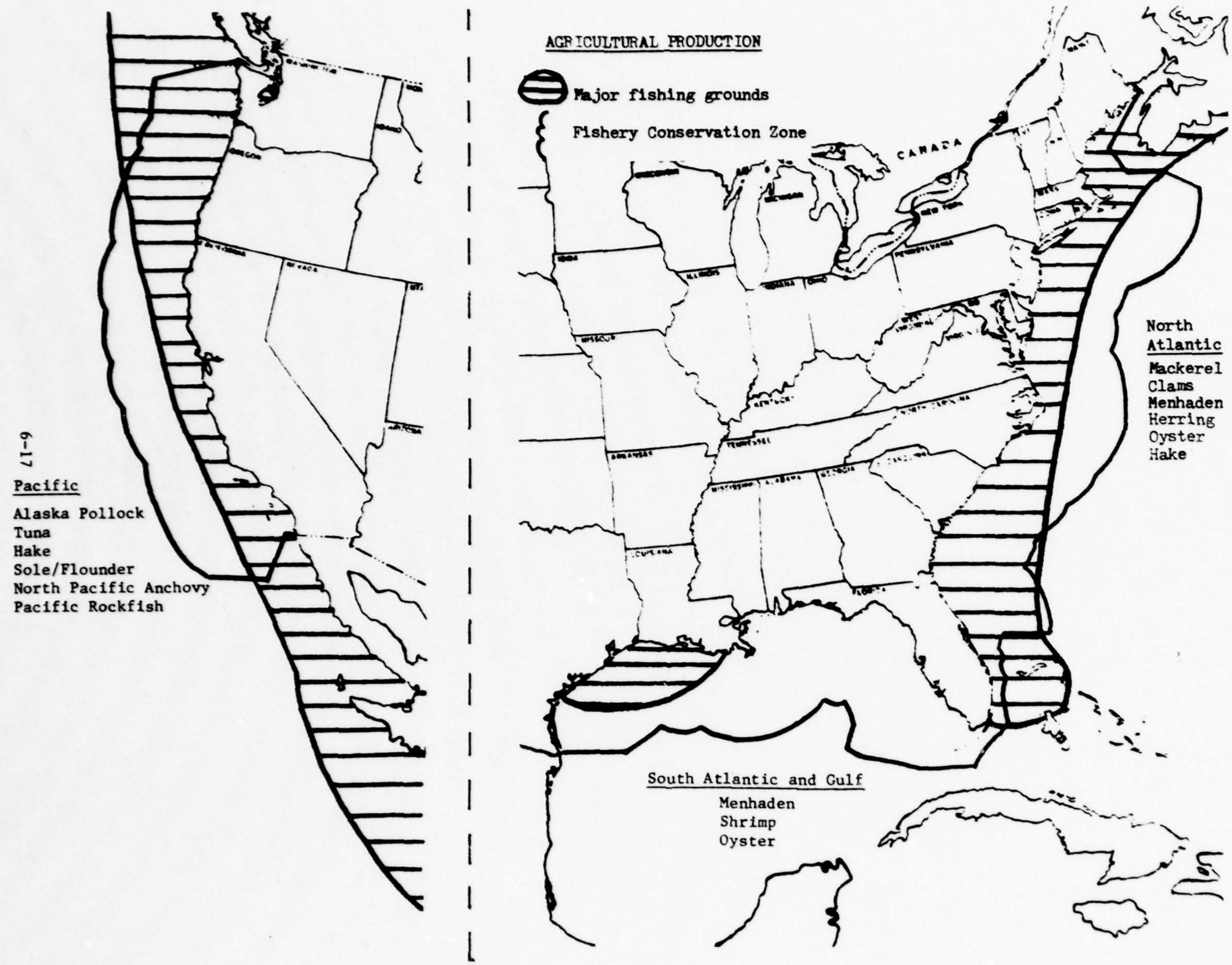
The developments stated thus far, the revitalization of the fishing industry by utilization of new equipment, an allotment system, the expansion into international waters, and the regional creation of marine management zones will increase substantially the total marine agricultural production and enhance the likelihood for exportation. As the ocean environment adapts the composition of the land agricultural production cycle, "planting, fertilizing, harvesting," total marine production of all species should increase substantially beyond national needs. The exportation would be another extension of the U.S. agricultural system in terms of its importance to world food supplies.

As marine activities increase overall, educational opportunities will accelerate rapidly to train the required personnel to manage and develop these events. However, after many underwater activities are in an operational stage, the trained personnel could be displaced from an over-supply and from lack of employment opportunities. This would be a similar situation to the aerospace engineers.

FIGURE 6-3: TAILORED VIGNETTE - AGRICULTURAL PRODUCTION

FORECASTED DEVELOPMENTS	PROBABILITY/TIMING		
	1981-85	1986-92	1993-2000
AGRICULTURAL PRODUCTION IN MARINE ENVIRONMENT IS SELECTED AS A FUNDAMENTAL COURSE FOR CONTINUED FOOD GENERATION AND BYPRODUCT OPPORTUNITIES	G	G	H
CONSUMER INTEREST IN MARINE PRODUCTS REMAINS VIABLE	H	H	H
FISH INDUSTRY SEEKS REVITALIZATION BY:			
• EMPLOYING NEW EQUIPMENT	G	G	G
• RECONDITIONING OLD EQUIPMENT	G	G	L
• ADOPTING MANAGEMENT/CONSERVATION CONCEPTS	G	G	H
REVITALIZED FISHING INDUSTRY EXPANDS INTO INTERNATIONAL WATERS ADOPTING ADVANCED CONCEPTS OF THE FLOATING FACTORY	M	L	G
DETECTION AND SENSING SYSTEMS UTILIZED FOR			
• ISOLATION OF MIGRATORY SPECIES	L	G	G
• MONITORING OF CULTIVATED MARINE SPECIES INCLUDING PLANTS	L	G	G
DETECTION SYSTEMS INCREASING ROLE, WITH UNMANNED PASSIVE SYSTEMS	L	G	G
HARVESTING ADVANCES INCLUDE			
• ADOPTION OF NEW NETTING SYSTEMS	G	G	G
• ELECTRONIC STUNNING	M	L	G
• CHEMICAL BARRIERS	M	L	G
ESTABLISHMENT OF FISH AND MARINE PLANT FARMS TO AUGMENT SIZE OF HARVEST	M	L	G
MARINE PRODUCTION BECOMES NATIONAL PRODUCT TO EXPORT, WITH SIGNIFICANT FAVORABLE ECONOMIC IMPACT	L	G	H
RECREATIONAL FISHING COMPETES WITH COMMERCIAL FISHING INTERESTS	G	H	G
ZONED AREAS CREATED FOR RECREATIONAL FISHING	L	G	G
AQUACULTURE PRODUCTION UTILIZES "TOTAL SYSTEM CONCEPTS" CREATING COMPLEX UNDERWATER AREAS FOR THE CULTIVATION AND HARVEST OF A VARIETY OF MARINE SPECIES	L	L	G
KELP/BIOMASS ADOPTED AS SOURCE OF ENERGY PRODUCTION	M	L	G

Key:
M = Minimal
L = Low
G = Good
H = High


AGRICULTURAL PRODUCTION
Major fishing grounds
Fishery Conservation Zone
CANADA
North Atlantic
Mackerel
Clams
Menhaden
Herring
Oyster
Hake
South Atlantic and Gulf
Menhaden
Shrimp
Oyster
Pacific
Alaska Pollock
Tuna
Hake
Sole/Flounder
North Pacific Anchovy
Pacific Rockfish

CHAPTER 7: TRANSPORTATION

DEFINITION

For purposes of this analysis, transportation activities are defined as those procedures and processes involved in moving persons, messages, materials, equipment, or forces, such as electricty, from one place to another. Transportation, when viewed from a functional perspective, is an integral component of virtually every other activity category, and has been discussed conceptually in these categories. However, the instruments and methods of transportation share many common features regardless of the motivation behind them. It is these characteristics that bind together to comprise the underwater activities defined and discussed in this chapter. The approach to define operationally those underwater activities related to transportation is based upon the premise that it is generally not as important to U.S. Coast Guard operations to know why a given transportation activity is taking place as it is to know what the operations are and will be that involve transport, what methods for conducting these operations we can expect, and what locales, densities and operational systems a transportation system will entail. Of course, some exceptions to this rule emerge, for example, in the transportation of antisocial technological devices.

The underwater activities related to transportation generally can be divided into four basic classifications and ten specific transport activity areas reflected in Figure 7-1, following.

FIGURE 7-1: TRANSPORTATION

Basic Classification	Specific Transportation Activities
Port Operations	Inland Ports Coastal Ports Offshore Ports Surface Vessel Traffic
Underwater Vehicles	Submersibles, Self-Propulsion and Swimmer Delivery Systems, etc.
Diving	Recreational Commercial
Underwater Installations/ Structures	Pipelines Cables Tunnels, Bridges, and Causeways

BACKGROUND

Water has long played an important role in economic and social development both as an impediment and an enhancement to the flow of goods and people. The early settlement patterns of the United States and virtually all other nations have been heavily influenced by their accessibility to water as a means of transportation. As was discussed in Chapter 2 on military activities, it was centuries before water transportation meant anything other than surface transporttion. Today, however, the water provides a milieu for conduct of transportation activities on, below, and above the surface of the water.

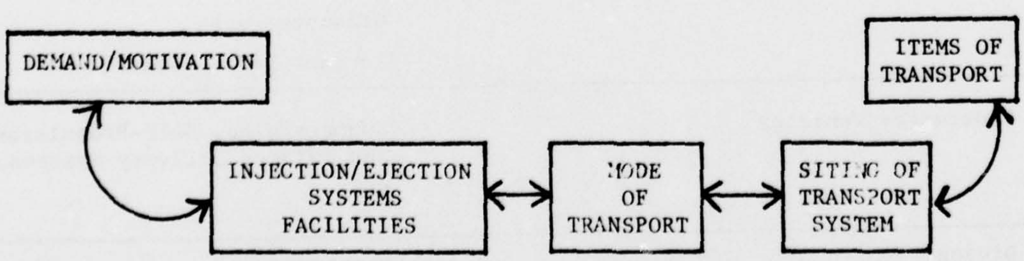
The dynamics which will provide a backdrop for future underwater transportation activities include:

- The accelerating development of offshore commercial activity
- Increasing volumes of international trade and diversity of items transported and purposes of transport
- Expanding problems of density and multiple use of traditional sea areas
- Significantly increased risk of the incidence of transportation related accidents plus the increased damage which such accidents can potentially render

FUNCTIONAL SYSTEM

The functional system essentially connects a demand for movement with the item(s) to be moved. The major components of the overall functional system for underwater transportation are outlined in Figure 7-2.

FIGURE 7-2: MAJOR COMPONENTS OF OVERALL FUNCTIONAL SYSTEM



Demand/Motivation Systems

As is the case in all other functional systems within the Underwater Activities Systems Model, the actual underwater transportation activities are derived from demands, motivations, and objectives outside the function of transportation itself.

Generally speaking, these demand/motivational systems may be classified as follows:

- Need to move materials or persons from one point to another via water as a medium for transport
- Need to move materials or persons from one point to another through some conduit which passes through, or a bridge which passes over, water
- Need to transport communication messages through a cable or communications network which passes through water, such as telephonic or telegraphic cable systems
- Need to transport basic forces, such as electricity, from one point to another

As was noted above in the definition section, the particular motivation is usually of secondary importance. It does not matter as much that a diver is moving in a submersible for recreational pleasure or for inspecting a pipeline, as it does that he is moving with a particular type(s) of equipment, in a particular place, and at a particular time. The purposes for which antisocial technological delivery may be occurring is of secondary importance to the sheer fact that it is occurring and must be confronted immediately on those terms alone.

Item(s) of Transport

The next component is the item(s) to be transported. As has been noted, this item may be a person, many persons, materials in various forms, messages, vehicles, and/or electricity.

Siting of the Transportation Systems/Functions

Transportation is used as a generic concept, but it is closely related to other purposes or objectives and will occur in various locations on those terms. Thus, if there is an underwater network of oil wells/pipelines from ocean-bottom rigs, this will determine the type of transportation that will be involved in both the operation of the underwater oil wells and in the transportation of the crude oil to an inland, coastal, or offshore refinery.

Recreational diving, on the other hand, usually will be sited where the various waters and environmental characteristics of the underwater area are consistent with these motivations and needs. Hence, the systems for siting the transportation activities will be derived from and closely related to the particular demands/motivations to which the transportation relates.

Mode of Transport

Another major component for this category relates to the particular mode of transport which might include any of a large variety of different vessels designed to operate above, on or below the surface.

In another vein, the transportation mode for an individual swimmer or diver is the individual organism itself, functioning in this sense as a vessel to propel the individual from one point to another. Specialized equipment such as suits and air tanks are a component of this individual organism's function as a vessel.

Injection and Ejection Facilities

These are the facilities such as ports which provide a linkage through which the items being transported will flow into and from the transportation systems. Such facilities may include ports, inland or offshore refineries, and simply the point of entry or exit from the underwater/marine environment.

GEOPHYSICAL PERSPECTIVES

Transportation activities are heavily affected by geophysical phenomena. The type of boat which can be accommodated within a given area depends upon the depth and width of the channel or the sea. The type of diving which can be done is determined by a combination of depth and temperature, as well as purpose.

In the paragraphs below,the basic geophysical perspectives related to each of the underwater transportation areas are outlined.

Inland Ports

Inland ports need to be placed adjacent to inland waterways which can accommodate the needed vessels and/or transportation units. If vessels are to be accommodated, ports need to be on waterways which connect with the open sea. The Great Lakes and St. Lawrence Seaway, the Mississippi River and its tributaries, and the Potomac River are examples. The advent of barges carrying hugh volumes of materials but drawing little draft have opened significantly the range of places where inland ports may be located.

A less well-defined type of inland port is the pipeline connection which connects the offshore transportation system of oil or minerals mined offshore, for example, with inland refineries or transportation networks. These types of facilities can occur wherever the refinery or "hook-up" is located.

Coastal Ports

The most obvious geophysical requirement for coastal ports is that they be in a coastal area. In general, Baltimore is considered a coastal port although it could be defined technically as an inland port.

In addition to being along the coast line, coastal ports must be located in areas which form a harbor that is sheltered or in which some type of shelter can be constructed. Historically, this limitation plus some restrictions on dredging technologies have influenced heavily the location of major coastal ports to areas with a "natural harbor" offering both the needed "shelter" and the needed depths.

Given current and future technology, coastal ports could be constructed in many other places, through a combination of dredging and artificial island buidling. However, the time, cost, and environmental issues associated with such a massive undertaking probably will act to limit the actual construction of ports making even future locations determinable largely by the historic factors of "natural harbor" and depth. There still are several potential sites which could be used along the coast of the U. S. and its territories.

Offshore Ports

The typical basis for the concept of offshore ports is that they can be located in depths which will accommodate the emerging superships such as the supertanker. Another reason may relate to the remoteness of such facilities when handling dangerous materials, such as liquified natural gas.

These offshore ports can be located virtually anywhere the depths are sufficient to carry the desired form of vessel. Although they will not likely occur during the period of this forecast, serious consideration will soon be given to offshore ports in the traditional sense of the term. In general, current concepts would limit offshore port facilities to those areas where the natural depth of the water easily will accommodate vessels drawing a draft of over 100 feet.

Submersibles

Some form of submersible is capable of operating within any underwater area of the territorial waters of the United States. Some of the deeper troughs off both coasts may carry depths which are beyond the operational capability of anything other than special purpose military submarines or deep diving bells. However, in a generic sense, submersibles as part of the class of underwater vessels generally are not limited by geophysical factors.

A given type of submersible is limited considerably by factors such as depth. In general, depths of up to 1000 feet are rather "easily" attainable within current technology for general purpose commercial activities. Specialized military and scientific craft go many times deeper.

Diving

Diving is defined for purposes here as transportation of a person within the underwater environment without the aid of a vessel; i.e., the person is not in a submersible. At the current time, commercial diving operations are possible through the aid of a JIM suit to depths beyond 1000 feet. Temperatures and other geophysical features can be dealt with through appropriate personal equipment.

Recreational diving, on the other hand, generally is more limited to depths of about 100 to 125 feet.

Of course, within these depth limits, diving can occur anywhere.

Cables and Pipelines

Cables and pipelines may be laid anywhere by simply dropping preready cables or pipelines into the water. Such facilities are actually placed only in sites where they can be approached via some form of submersible. This permits appropriate mooring and maintenance activities. Cables stretching entire oceans, however, may be laid in deeper and inaccessible spots. However, given the greater efficiencies of satellite communication devices, it is most likely that few, if any, such underwater cables will be used, and certainly not extensively.

Tunnels, Bridges and Causeways

Tunnels, bridges, and causeways are constructed to connect to land points interrupted by bodies of water. This permits land transportation vehicles to traverse over the marine environment.

Tunnels are limited by the geological structure of the earth if they are to be underground. Structures need to provide support for the earth above the tunnel, with the shoring-up of concrete and other made-made materials and devices. Greater limitations relate to the ability actually to bore through the earth. In general, it seems unlikely that such concepts as a transatlantic tunnel will become a reality, even in a serious planning sense, for years. However, the concept of prefabricated tubes which can be laid in sections and then "sunk" and pumped out can lower significantly the cost of tunnels. Generally, "tube tunnels" can be laid anywhere there is a need to connect two land points so long as the depths of the water does not present pressures which cannot be sustained. Tunnels can be expected to continue to connect land areas in much the same manner they have been used traditionally, i.e., inland waterways, bays, etc.

Bridges are more constrained by distance or span than are tunnels. Although there is little technological reason that a bridge could not be built by laying section-after-section for an area the entire length of the Chesapeake Bay, economic factors most likely will preclude the employment of any such concepts. Thus, bridges are, by and large, limited to spans of a few miles.

Causeways, in general, are used to provide artificial fill for a roadbed from point-to-point. Barriers which may be constructed for other purposes

such as sheltering an area may double in use as a causeway. In general, causeways are employed only in relatively shallow water.

Tunnels, bridges and causeways are normally associated with inland or coastal areas and will likely remain so for the forecasted period of this study.

TAILORED FORECAST

BASIC CONCEPTS

Demand/Motivation Systems

Underwater transportation activities are primarily stimulated by and operate in relation to the needs associated with every other category of activity within the Underwater Activities System Model. (see page 1-7). In general, these can be conveniently grouped within the following headings:

- Military operations
- Application of antisocial technologies for nonmilitary purposes
- Movement of personnel, goods and/or services from one land base to another
- Movement of personnel, goods and/or services from one offshore base to another
- Recreation/pleasure
- Scientific research
- Logistical services of other marine based activities
- Protection, rescue, salvage, law envorcement, etc. related to other activities.

Items of Transport

As has been discussed elsewhere, practically anything can be an item of transport. It may be a physical item, or a force such as electrical current. In general, the items for transport may be classified as follows:

- Persons or physical materials (physical in the sense of a three dimensional object or substance to be carried)
- Forces of "nonphysical" items (nonphysical in the sense of not being a three dimensional object or substance to be carried)

Given the growing interdependence of the world, it seems most likely that any item which may be involved in transportation on land must also be considered a candidate for transportation within the marine environment. Thus, this includes goods/services of a illegal nature such as drug traffic or smuggled.

goods which are, in a sense, within the world economy, but are often considered so in a specialized manner. Finally, it includes any item being transported for a military purpose or for the purpose of application of some form of antisocial technology.

For purposes of this forecast, it is useful to classify this diverse and almost limitless set of items as follows:

- Solids - nonhuman
- Liquids and solvents
- Dangerous cargo (solid or liquid)
- Extra-legal items
- Personnel - individual
  group

Just as important as the item to be transported is the volume of the item. For example, heavy volumes lead to concepts of much larger vessels, such as the super tankers. Thus, there is a further need to break down each of the above concepts among very high volume tonnage/space requirements, mid-range volume tonnage/space requirements, and low volume tonnage/space requirements. These volume perspectives primarily determine the specific size and type of vessels or modes of transport which will be used.

Siting of Transportation System

In general, siting of systems is a function of the purposes of transport and the items and volumes of transport. Siting hinges upon where certain functional activity occurs, including:

- Offshore areas of commercial exploitation
- Land-based industrial activity
- Underwater scientific activity
- Recreational areas
- Metropolitan centers
- Conveyances for land vehicles (tunnels, bridges, causeways, ferries)

Modes of Transport

The modes of transport which are related to underwater activities are generally classifiable into the following categories:

- Cargo vessels
- Personnel vessels
- Underwater vessels/vehicles
- Pipelines
- Cables
- Land vehicles interconnecting port facilities
- Tunnels, bridges, causeways

Injection/Ejection Facilities

The basic facilities which connect the marine environment to the land environment are important to the overall concept of future underwater activities related to transportation.

These facilities may be grouped as follows:

- Ports

Inland	Materials handling facilities
Coastal	Containerization
Offshore	Vessel modal accomodation

Materials handling facilities have undergone substantial improvements during the last decade alone. Cranes and various other loading and unloading devices are able to move larger materials in shorter amounts of time, employing a smaller number of support personnel to operate them.

The trend towards containerization of shipping material already has become very evident. Containerization has proven to be especially cost efficient/productive for moving larger volumes of material, achieving the maximum utilization of space on cargo ships, and lessening the difficulty and decreasing the time frequently associated with loading and unloading.

The containerization and modularization of ships also have greatly enhanced intermodal ease and efficiency. Material can be unloaded directly from or onto railroad flatcars, attached or unattached from tractor trailer cabs, or placed upon or lifted from flat-bottom trucks.

Key Driving Forces, Key Barriers, and Obviating Factors

Figure 7-3 briefly outlines the driving forces, barriers, and obviating factors essential for forecasting underwater transportation related activities.

FIGURE 7-3: TAILORED FRAMEWORK: UNDERWATER ACTIVITIES RELATED TO TRANSPORTATION

BASIC CONCEPTS	KEY DRIVING FORCES	KEY BARRIERS	OBVIATING FACTORS
DEMAND/MOTIVATION SYSTEMS ITEM OF TRANSPORT • People • Materials • Messages • Vehicles • Electricity SITING OF TRANSPORTATION SYSTEMS • Offshore Areas of Commercial Exploitation • Industrial Activity • Scientific Activity • Recreational Areas • Cosmopolitan Centers • Water Body Barriers Between Land MODE OF TRANSPORT • Sea Surface Vessels • Underwater Vessels/ Vehicles • Divers • Pipelines • Cables • Land Vehicles • Tunnels, Bridges, Causeways INJECTION/EJECTION FACILITIES • Ports (all types) - Materials Handling Facilities - Containerization, Modularization - Vessels and Intermodal Accomodation	• Increasing amount of trade both domestically and internationally • Need/national priority to lessen economic dependency on foreign markets • Establishment of broad 200-mile economic zone lessening risks in heretofore unclaimed frontier areas • Rapidly developing technologies • Foundational/institutional role in the national economy/ society • Overall growing need to better understand the world around us • Frontier mentality • Growing need to enhance and/or improve transportation systems for working tasks in selected underwater environments • Continued evolutionary improvements in wide dispersion of national and international communication networks • Increasing amounts of recreation/leisure time	• Comparative economic costs • Inadequacy of present capabilities to handle emerging vessels • Environmental effects uncertain • Increases likelihood of accidents, other man-induced disasters • Incompatable National Policies • Uncertain or strict regulatory environment	• Significant decrease in trade, shipping volume traffic • Advent of alternative non-marine transport systems • Emergence of adverse public opinion for supertanker traffic due to occurrence of some major tanker accidents and spills of pollutants or dangerous substances • Broad decline in recreational/ commercial interest in marine/underwater environment

The tailored vignette discusses in depth salient driving forces, barriers, and obviating factors.

TAILORED VIGNETTE

PORT OPERATIONS AND SURFACE VESSELS

Despite some efforts to develop national resource independence, *the continuing, rapid acceleration of world economic interdependency will persist at least until the end of the century.* As a result, we can expect a host of improvements and advances to take place in the area of port operations and surface vessels including:

- Absolute demand for greater trade levels, both domestically and internationally, will increase substantially
- Cargo carrying and transporting capabilities will become more efficient. The concepts of containerization and modularization will find greater application
- Significant expansion and improvement in port capability and capacity will occur in order to accommodate increasing ship traffic

The U.S. marine/underwater transportation network will play an important role in the above trends and developments. In order to retain international economic competitiveness, the U.S. economy will respond accordingly to the ongoing, rapid growth in international trade. Moreover, interstate trade within the U.S. will witness substantial growth due to expanding internal industrial output, increasing domestic consumption patterns, and the overall increase in the domestic demand for imported goods (ranging from basic commodity resources to consumer goods such as automobiles, television sets, etc.).

As the acceleration in U.S.domestic and world trade continues,this trend will become increasingly evident that U.S.port capability and capacity is lagging behind growing needs. An array of developments will indicate the need to fill this gap, including:

- Growing congestion of shipping lanes, channels, harbors
- High density of port handling facilities
- Increasing numbers of accidents involving
  - Ships carrying pollutant or chemically harmful substances
  - Land-based handling facilities and support personnel

- Significant back-ups in vessel loading and unloading operations, leading to long, uneconomical delays
- Inability of ports to handle future shipping fleets due to:
  - Outdated land-based port facilities
  - Shallow harbor depths restricting large ships from entering

The above trends are likely to change dramatically traditional concepts for port siting and operations. A number of investigative studies to determine alternative port siting appear likely during the early to mid-1980's. Initially, alternative siting will emphasize potential coastal port areas with geophysically attractive advantages over most U.S. ports, e.g., wider basins, deeper water to handle the larger draft of supertanker traffic. Yet as this development takes hold, other considerations will be taken into account. Additional criteria will include: availability of space for expansion subsequent to the construction of the new port/harbor; relative distance from moderately to densely populated areas; proximity to specialized cargo/material end points, e.g., refineries, power stations, steel mills, etc.

National priority for the siting and construction of offshore ports will gain momentum during the 1980's. Although offshore port development has not moved beyond the conceptual stage (due to institutional cautiousness, public sector restraints, and environmental concerns), this inert state will reverse itself in the next decade. We would expect one or two of the single point mooring (SPMs) proposals for the Gulf of Mexico to emerge as the first candidates. Initially, these SPMs (as well as others constructed during or after the erection of these sites) will transport only oil and gas via pipeline to and from the mooring site.

During the 1990's, technological improvement and advancement in offshore platform design, coupled with the evolving capability of pipelines to transport slurry material, will broaden considerably the capabilities of offshore ports to handle many additional materials other than liquids. Floating and fixed pile structure and design will become economically feasible for bulk cargo unloading and loading. Large container ships are likely to unload their cargo on these platforms for loading onto smaller vessels for further distribution to U.S. coastal and inland ports. These platforms also will serve as an unloading point for U.S. exports, later to be picked up by large supercargo carriers for distribuiton world-wide. Furthermore, it appear likely that an extensive network

of multipurpose pipelines will be connected to these offshore port centers. Mineral ore crushing facilities would be located at land-based end points to turn exported ore into slurry for transport through the pipelines to the offshore site for loading. Crushing devices might be employed on the platform itself to mash imported ore for national distribution via pipeline.

There will be a number of improvements in ship design and carrying capabilities to increase cost efficiencies in shipping. Supertankers for transporting oil and gas will prevail; both specialized and general purpose tankers will be part of the ship inventory for transporting various forms of liquid. Supercargo ships for transporting finished goods will witness a substantial increase during the forecast period. In order to maximize profitability, super cargo ships will be designed to carry specially fixed modular containers with various standard sizes. Super ore/other raw material cargo carriers are likely to find increasing application. Certainly smaller vessels will continue to be needed during the next 20-25 years, but they will be used predominantly in carrying freight to inland and coastal ports with fairly shallow harbors.

Growth in both large personnel carriers and recreational seafaring vessels is expected, but the rate of increase will be much greater for recreational craft. Over the course of the next 20-25 years, it is conceivable that it will be necessary to move huge masses of people across large bodies of water. These masses might be comprised of military troops, or perhaps refugees. Regardless of the cargo, there will be a number of personnel carriers of various types and sizes in the international ship inventory. As reacreation/leisure time increases, we would expect the number of pleasure craft to grow considerably. Private ownership of small to mid-size motor boats, sailboats, catamarans, etc. will expand. It seems likely that given price decreases in hydrofoils, private ownership will increase concurrently.

By the year 2000 we likely will see U.S. port capabilities and operations, as well as ship design, capability, and ownership, rapidly changing in response to an equally rapidly changing world and U.S. national economic and technological environment. As many as a half of a dozen, and perhaps more, multi-purpose offshore ports will be under construction or at the planning stage in U.S. territorial waters. A smaller number will be operating at near full capacity. Moreover, many alternative port sitings on land are likely to be completed; others will be under construction. As a result of this shift, we can expect to witness noteworthy shifts in population and industrial activity into or near these new port centers. This development alone will have a fairly favorable

implication for regionally equitable economic growth patterns in the U.S. Furthermore, an inventory of ship capabilities and design will demonstrate substantial efficiencies for trade and intermodal transportation. Private ownership of recreational vessels will increase, and the speed and load weight of these vehicles will increase considerably.

As the turn of the century approaches, the overall importance of port facilities as a useful component to equitable regional economic development in the U.S. will emerge increasingly clear. States with inland waterways and inland port facilities will request that this opportunity be seized. They will pressure local, state, and the national government networks for funds and technical assistance to upgrade and expand inland port facilities. Debates between waterways/river states and coastal states are likely to surface. Moreover, states with no coastal margin or waterways would conceivably lobby for large-scale transportation concepts heretofore not considered economically justifiable, e.g., super air cargo carriers, etc.

UNDERWATER VESSELS/VEHICLES

The number of operational submersible craft will increase over twofold before the year 2000. In addition, a sizeable number of these craft will be under construction at the turn of the century. Accelerating offshore commercial activity will act as the principle driving force. The demand for submersibles will not only originate from the needs of the offshore oil and gas industry, but also will be needed to inspect ore slurry pipelines, underwater habitats for mineral extraction and scientific research, etc. The demand for scientific mission submersibles also will increase as the inherent desire to better understand the complex underwater environment crystallizes. Military submarine operations conceivably could have a spillover effect for submersibles for use as cargo and personnel carriers. Yet even if this development should take hold,actual application outside of military operations is likely to be minimal before 2000. We do foresee, however, the use of a number of submersibles both here and abroad in the recreation sector. As underwater parks grow in scope and number, the use of submersibles to permit tourists to observe this intriguing environment seems highly likely before the turn of the century.

The emergence of more advanced and less expensive self-propulsion/swimmer delivery systems appears likely. Offshore/underwater commercial activity will be responsible for much of the development in this area. Commercial and scientific

diving operations will require systems which permit them to move at greater speeds and carry larger and heavier loads. As these technologies become more widely employed at the commercial level, it seems likely that smaller size units will become increasingly affordable for the recreation industry. Before the year 2000 we would expect a number of fairly sophisticated, highly mobile self-propulsion/swimmer delivery systems to be privately owned by persons traversing the underwater domain for purely recreational pleasure and enjoyment.

DIVING

Significant advancements will be made in both commercial and recreational diving equipment and capabilities. As a result, diving related activity will escalate sharply over the forecasted period. Offshore industrial/commercial activity will sponsor the development of diving equipment to permit deeper dives for longer intervals. Although most of this gear will be expensive, the recreation industry will develop gear with similar design, but will fall short of matching some of the more advanced capabilities of the gear employed in the commercial sector.

Both commercial and recreational diving within U.S. territorial waters will witness substantial growth rates in terms of the absolute number of dives and the number of individual divers. Commercial diving will take place wherever extensive commercial activity in the underwater environment is located, e.g., pipeline installation, drilling for oil and gas, etc. Greater use of one atmosphere diving suits permitting deeper dives will occur. Most recreational diving activity will continue to be confined along coastal margins in waters of 200 feet or less, although we can expect some adventurists to dive to greater depths.

UNDERWATER INSTALLATION/STRUCTURES

The use of cables in the underwater environment will witness an uneven rate of development, depending on the functional purpose of the cable laid. Satellite communication technology, as well as other above sea transmission devices, will offset considerably further growth in cable laying at the bottom of the sea for communication systems. Cables will become increasingly important as a mode to transport electricity to selected population/industrial centers. In our energy vignette, we discussed how the offshore electrical energy production network is likely to expand considerably over the next 20-25 years (see energy vignette Chapter 4 for greater detail). Cables will serve as the principle mode of electrical transportation and distribution form these offshore

generating sites. Due to the close proximity of offshore energy producing sites such as those envisioned, it is probable that this cable will be laid in relatively shallow waters. In order to avoid the scraping of these cables by bottoms of large ships, and the possible entanglement of these lines from vessel anchors, most of the cable laid will need to be buried beneath the seabed.

As discussed previously in this chapter and in other parts of this report, the deployment, use, and function of pipelines in the underwater environment will expand dramatically over the forecast period. Initially, pipelines will be linked to offshore oil and gas operations, including offshore ports for transporting petroleum to land-based refineries. The rate of growth in offshore oil and gas extraction activities is forecasted to accelerate significantly over the next decade alone. Assuming the discovery of sizeable deposits of oil and gas in the U.S. Atlantic OCS and offshore Alaska, the demand for pipelines will be boosted substantially. Pipelines will be used to interconnect large clusters of drilling wells into one distribution platform/mooring point for loading onto vessels. Wells fairly close to coastal margins conceivably could inject the oil and gas extracted via pipeline directly to land-based refineries. Later in our forecast period, the concept of slurry pipelines will gain momentum, and find notable application in the underwater environment towards the year 2000. Offshore multi-purpose ports and underwater extraction sites seeking to mine coal or other minerals will crush the ore, mix it with seawater, and transport the slurry to key destination points. *In sum, the offshore (and probably on land as well) pipeline industry will emerge as one of the most dynamic, fastest growing industries in the U.S. economy, and will no doubt find an equally rapid growth in many other parts of the world community.*

The automobile will continue to retain its preeminance in U.S. society. Although probable changes in design and propulsion are likely over the forecast period, individual/family ownership of the auto will remain crucial for keeping intact the desire held by most of the nation's population to be mobile and independent, when necessary, of potentially unpredictable, frequently expensive mass transportation alternatives. *Hence, the construction of tunnels, bridges, and causeways to permit more convenient movement of cars and trucks across and under the marine environment are likely to witness continued growth.* Most of the water bodies acting as obstacles already have been crossed. The Chesapeake Bay Bridge-Tunnel serves as one example. The U.S. area mainly consists

of a large continental mass, and although a bridge or Trans-Pacific tunnel from Los Angeles to Honolulu would surely facilitate tourist travel to and from Hawaii, the intense, seemingly insurmountable engineering needs, let alone the exorbitant costs of such a venture, obviate the possibility of such a concept during this century and beyond. Yet there are many nations in the world which have yet to conquer smaller impediments to domestic travel; it seems evident that they will make a considerable effort to close the gaps between intra-national transportation networks. At this time, for example, the Japanese are involved intensely with the construction of a vast maritime bridge and tunnel project aimed at interconnecting their nation's four largest islands. Most bridge, tunnel and causeway construction in the U.S., however, will be aimed at increasing the capability of structures already in operation rather than developing vast plans to interconnect portions of the nation as yet not linked. The construction of a second Chesapeake Bay Bridge, parallel to the older bridge, has partially offset the long (both in terms of distance and time) back-ups moving east and west across the bridge during the tourist season.

Although we do expect some degree of land-based tunnel demonstrations and experimentations employing air suspension techniques, we do not foresee the deployment of this concept in the marine/underwater environment. The front end development costs will be considerably high for this technology. The pursuit and construction of a "tube" tunnel underneath the seabed would only drive costs up more.

FIGURE 7-4: TAILORED VIGNETTE - TRANSPORTATION

FORECASTED DEVELOPMENTS	PROBABILITY/TIMING		
	1981-85	1986-92	1993-2000
LEVEL OF WORLD INTERDEPENDENCY AND TRADE CONTINUES TO INCREASE	H	H	H
INABILITY/INADEQUACY OF U.S. PORT CAPABILITIES/CAPACITY TO HANDLE GROWING VOLUME OF TRADE	G	H	H
- TRADITIONAL ECONOMIC PORT SITING NEAR LARGE POPULATION/ DISTRIBUTION CENTERS GRADUALLY ERODES	G	H	H
• CONVENTIONAL SHIPPING LANES BECOME MORE CONGESTED	G	H	H
• UNREASONABLY HIGH POLLUTION LEVELS AGGRAVATE PORT VIABILITY NEAR LARGE POPULATIONS	G	H	H
• SHIP SIZE CONTINUES TO INCREASE, PUTTING FURTHER PRESSURE ON PORT DEPTH LIMITATIONS	H	H	H
• NEED TO ENHANCE/IMPROVE MARINE RECREATION AREAS NEAR LARGE POPULATION CENTERS INCREASES	H	H	H
• OUTDATED U.S. PORT HANDLING FACILITIES REQUIRES CONSIDERABLE INTERNAL HARBOR INVESTMENT/RENOVATIONS	G	H	H
- U.S. INLAND PORTS CONFRONT GROWING COMPETITIVE PRESSURE FROM COASTAL/OFFSHORE COUNTERPARTS	G	G	H
EXPLORATION/INVESTIGATION INTO NEW HARBOR/POST SITINGS	L	G	H
- PHYSICALLY ATTRACTIVE SITES DETERMINED BY NATURAL SETTINGS MORE CONDUCIVE TO NEEDS, E.G., WIDER BASINS, DEEPER WATER, ETC.	L	G	H
- NEW SITES SIGNIFICANTLY DISTANT FROM LARGE POPULATION CENTERS	L	G	H
- NEW SITES LOCATED CLOSER TO SPECIALIZED CARGO END POINTS, E.G. REFINERIES, POWER STATIONS, STEEL MILLS, ETC.	L	L	H
BEGINNING OF NEW ERA IN AREAS ONCE FAIRLY UNDERDEVELOPED/ SPARCELY POPULATED	L	L	G
- SPECIALIZED PORTS BEGIN CONSTRUCTION	L	G	H
- COMPLEMENTARY END POINT UNIT, E.G. REFINERIES, STEEL MILLS, ETC., RENOVATED CONSIDERABLY OR EVEN NEWLY CONSTRUCTED	L	G	H
- CONSIDERABLE SHIFTS OF POPULATIONS TO NEW PORT CENTERS	L	L	G
OFFSHORE PORT CONSTRUCTION IN U.S. WATERS USING TRADITIONAL SPM CONCEPTS BEGIN CONSTRUCTION	G	H	H
- OFF GULF COAST	G	H	H
- OFF EAST COAST	L	G	H
- OFF WEST COAST	L	G	H
- OFF ALASKAN COAST	L	G	H
- EMPLOY EXTENSIVE NETWORKS FOR COMMODITY/CARGO DISTRIBUTION	L	G	H
• LIQUID PIPELINES	H	H	H
• SLURRY PIPELINES	L	G	G
ADVANCEMENT IN FLOATING AND FIXED PLATFORM STRUCTURE AND DESIGN	H	H	H
- EXPANDS FEASIBILITY OF BULK COMMODITY/CARGO LOADING AND UNLOADING OF OFFSHORE PLATFORMS	L	G	G
- AND IS LOCATED IN U.S. WATERS	L	G	G

(CONTINUED)

FIGURE 7-4: TAILORED VIGNETTE - TRANSPORTATION (CONTINUED)

FORECASTED DEVELOPMENTS	PROBABILITY/TIMING		
	1981-85	1986-92	1993-2000
SHIP DESIGN WILL CONTINUE TO EMPHASIZE "SUPER" CONCEPTS AND OTHER PROCEDURES TO MAXIMIZE TRANSPORT EFFICIENCY	H	H	H
- SUPERTANKERS FOR TRANSPORTING OIL AND GAS	H	H	H
• SPECIALIZED TANKERS FOR LIQUIDS	H	H	H
• GENERAL PURPOSE TANKERS FOR VARYING TYPES OF LIQUIDS	G	H	H
- SUPERCARGO SHIPS EMPHASIZING:			
• CONTAINERIZATION	G	H	H
• MODULARIZATION	G	H	H
- SUPER ORE CARRIERS	L	G	H
- SMALLER VESSELS USED PREDOMINANTLY FOR TRAVERSING SHALLOW INLAND WATERWAYS/PORTS	G	G	H
- LARGE PERSONNEL CARRIERS FOR TROOPS OF OTHER MASSES OF PEOPLE	L	G	G
- RECREATIONAL CRAFT WITH MUCH GREATER SPEEDS	G	H	H
• LARGER OVERALL PRIVATE OWNERSHIP OF VARIOUS RECREATIONAL CRAFT EXPECTED	G	H	H
• USUALLY INCLUDE SMALL TO MID-SIZE CRAFTS	H	H	G
• HYDROFOILS AND OTHER NEW TYPES OF CRAFT BECOME ECONOMICALLY FEASIBLE FOR PURCHASE/MARKETING IN RECREATIONAL SECTOR	M	L	G
ACCELERATING DEMAND/ACTIVITY IN OFFSHORE COMMERCIAL AREAS AND MILITARY OPERATIONS PROVIDES SIGNIFICANT SPILLOVER IN UNDERWATER VESSEL CONSTRUCTION/ADVANCEMENT	G	H	H
- NUMBER OF SUBMERSIBLE CRAFT OPERATIONAL INCREASES MORE THAN TWOFOLD OVER CURRENT INVENTORY NUMBERS	M	L	H
- SUBMERSIBLES ARE USED EXTENSIVELY FOR COMMERCIAL OPERATIONS AROUND U.S. WATERS	G	H	H
• OIL AND GAS INDUSTRY	H	H	H
• OTHER RESOURCE ASSESSMENTS SUCH AS MINERALS, FISH, ETC.	L	G	G
- SELECT NUMBER OF SUBMERSIBLES CONTINUE UNDERWATER SCIENTIFIC EXPLORATION	H	H	H
- SMALL NUMBER SUBMERSIBLES EMPLOYED AS UNDERWATER CARGO CARRIERS (NON-MILITARY NATURE)	M	L	G
- FEW SUBMERSIBLES EMPLOYED AS PERSONNEL CARRIERS (NON-MILITARY NATURE	M	L	G
- FEW SUBMERSIBLES EMPLOYED FOR RECREATIONAL PURPOSES SUCH AS MARINE OBSERVATION RIDES	M	L	G
MORE ADVANCED SELF-PROPULSION/SWIMMER DELIVERY SYSTEMS EMERGE	H	H	H
- ARE ABLE TO TRAVERSE MUCH FASTER UNDERWATER	H	H	H
- ARE CAPABLE OF CARRYING LARGER AND HEAVIER LOADS, MORE PASSENGERS	H	H	H

(CONTINUED)

FIGURE 7-4: TAILORED VIGNETTE - TRANSPORTATION (CONTINUED)

FORECASTED DEVELOPMENTS	PROBABILITY/TIMING		
	1981-85	1986-92	1993-2000
- SMALLER SIZE UNITS BECOME MORE WIDELY AFFORDABLE AND ARE OWNED BY GROWING NUMBER OF RECREATIONAL USERS	G	G	H
SIGNIFICANT ADVANCES WILL BE MADE IN BOTH COMMERCIAL AND RECREATIONAL DIVING ACTIVITY	H	H	H
- ALL TYPES OF DIVING RELATED ACTIVITY WILL INCREASE SHARPLY	G	H	H
- EQUIPMENT WILL EMERGE PERMITTING DEEPER DIVES FOR LONGER INTERVALS	G	H	H
- MOST OF ADVANCED EQUIPMENT WILL NOT BE COST AFFORDABLE FOR RECREATIONAL SECTOR	H	G	G
- RECREATIONAL DIVING WILL WITNESS SUBSTANTIAL GROWTH IN TERMS OF NUMBER OF DIVERS AND NUMBER OF DIVES	H	H	H
- MOST RECREATIONAL DIVING ACTIVITY WILL BE CONFINED ALONG COASTAL MARGINS IN WATERS OF 200 FEET OR LESS	H	G	L
RAPID GROWTH IN ABOVE SEA/AIR/SPACE COMMUNICATIONS WILL OFFSET, OR AT LEAST LIMIT CONSIDERABLY GROWTH IN UNDERWATER CABLE LAYING AND BURYING	G	H	H
AS OFFSHORE ELECTRICAL ENERGY PRODUCTION INCREASES (SEE ENERGY VIGNETTE) CABLES FOR TRANSPORTING ELECTRICAL ENERGY WILL UNDERGO GREATER DEPLOYMENT AND APPLICATION	L	G	H

M = minimal   G = good
L = low   H = high

CHAPTER 8: INJECTION OF FOREIGN ELEMENTS FROM MAN'S ACTIVITIES

DEFINITION

In recent years, as the concerns for environmental quality have grown, it has become customary to equate man's emission of foreign elements into the environment as pollution. This concept of pollution carries an inherent negative connotation and portrays inaccurately the full implications. Accordingly, in this chapter and in the category of activities, we have avoided the term "pollution" in favor of the more neutral term "injection." Injection is descriptive of what transpires without ascribing a "value" connotation on desirability. This is an important distinction to be made, for there are many ways in which injection of residuals from human activities is a desirable and acceptable procedure to be employed.

Thus, "injection of foreign elements" is defined as the ultimate deposit into the underwater environment of all net residuals/materials which originate from man's activities.

Injections may occur either deliberately, accidently or unconsciously. The specific activities defined within this category vary significantly depending upon how the injection occurs. These distinctions are classified into four basic groups with the associated injection activities for each:

DELIBERATE INJECTION
- Municipal Residuals
- Industrial Residuals
- Dredge Residuals
- Marine Operations
- Radioactive Materials

ACCIDENTAL INJECTION
- Municipal Residuals
- Industrial Residuals
- Marine Operations
- Radioactive Materials

SUBLIMINAL INJECTION
- Runoff
- Atmospheric Settling

MANAGED INJECTION

Nutrients

Ecostabilizers and Restorers

Naturally "Disposables"

Artificial Reefs and Barriers

BACKGROUND

The ensuing discussion and forecasts of underwater activities related to the injection of materials from man's activities considers the underwater environment as a depository for net residuals of wastes from human activities conducted on land, on and above the surface of the ocean, and within the underwater environment.

Throughout history man has used water as a waste disposal system. There has been little regard for the implications or effects of such actions until the relatively recent years of the mid-twentieth century. As waste materials began to wash back ashore, disrupting the beach, the shore living and recreation areas, efforts were initiated to transport the deposits further out to sea. Nonetheless, the underwater environment has long been regarded as a perfectly acceptable "dump."

More recently, environmental sciences have indicated that there are often serious consequences to overloading these "marine dumps" whether with respect to the inland waterways or the ocean.

The contemporary scene is one in which the polluting effects of foreign injections seems to be uppermost. Laws prohibit dumping of solid municipal wastes into the oceans, bilging of vessels, and various other forms of deliberate injection.

However, for purposes of this analysis we have considered these pollution concerns to be only a part of the overall perspective. The underwater environment may also be appropriately regarded as an effective and efficient waste processing system for many kinds of waste materials. There are many reasons to employ this natural waste disposal capability as a component of our overall waste disposal system.

Beyond this natural waste disposal processing is the further concept that some foreign materials may be manipulated in such a manner as to increase the productivity of some of the economic activities conducted within the underwater environment. For example, fish populations may be increased, and fishing grounds significantly controlled in terms of location by the adding of nutrients

which are present in many wastes. Beyond these wastes, implantation of desired nutrients can also be a major boost to marine agricultural productivity.

Thus, the underwater activities forecast is developed from the viewpoint that injection of foreign materials into the marine environment needs to be managed from at least the following perspectives:

- As a natural waste processing disposal system
- As an economic production system
- As an acceptable depository
- As an unacceptable depository

The overall trends of foreign injection will be set against a complex mosaic of ocean and land related activities, many of which will have secondary impacts on injection. Some of the broader macro/environmental constructs in which these activities will occur include:

- An accelerating industrial expansion in major coastal areas
- An increasing utilization of the ocean to support a variety of activities including mining, energy, military, fishing activities
- New detection mechanisms to measure subliminal and indirect inclusion of material
- Debates surrounding the concept of the inherent "economic rent" of the ocean as a depository for the waste of human activity
- Development of concepts to use injection as part of a total ocean-related system, for example, conditioning municipal sludge to be a nutrient or substrate for aquacultural systems

FUNCTIONAL SYSTEM

The basic functional system involves a series of activities which generate injection materials, a definitive concept of results which are desired to be achieved as a consequence of underwater injection activities and the connecting injection systems which bring these two ends together.

As is seen in Figure 8-1 each of these general components is comprised of a series of sub-components or systems.

FIGURE 8-1: FUNCTIONAL SYSTEM:
INJECTION FOREIGN ELEMENTS FROM MAN'S ACTIVITIES

Generating Systems	Injection Systems	Desired End Results
Municipalities/Communities Industrial Processing/ Commercial Activities Dredging/Excavation Marine Operations Other	Modes of Injection Deliberate Accidental Subliminal Positively managed Injection Management Systems Designating Standards Monitoring status Zonal control Remedial reactions	Economic/Effective Disposition of Wastes Nondegraded Underwater Environment "Managed" disposal Process Natural disposal system Acceptable dump Controlled enviromental upgrading

GENERATING SYSTEMS

The generating systems include:

- Residuals from the existence of municipalities which accrue largely as a result of the fact that cities or urban centers exist: These are normally the type of residuals that would result from local governmental waste disposal responsibilities and regulations
- Residuals from industrial processing/commercial activities: These are the wastes to be managed and disposed of through nongovernmental responsibilities and are a component of the private waste disposal management systems
- Residuals from dredging/excavation: The residual material which has been displaced by dredging or excavation opeations and which needs to be relocated
- Residuals from maring operations: All of the wastes and residuals resulting from activities within the marine environment that are injected into the underwater environment

Modes of Injection

Any of the preceding generating systems may make their injections into the underwater environment through any of four basic modes:

- Deliberate injection: Includes direct delivery dumping; pumping sewage directly into the underwater environment from a waste disposal facility; loading the material onto vessels and dumping at sea; or pumping the material out into the sea to get it a sufficient distance from the shore to preclude washing back or other undesirable environmental consequences close to the shoreline
- Accidental injection: Includes accidents that create spills or necessitates injection
- Subliminal injection: Includes runoff and materials which have become suspended in the atmosphere and are deposited into the marine environment
- Positively managed injection: Anything which is sought for injection into the marine environment as a means of increasing its economic productivity, including its value as a natural waste disposal system

INJECTION MANAGEMENT SYSTEMS

Injection management systems include:

- Systems to designate standards: Characteristically to date such systems have been largely oriented to determining pollutants and prohibiting them. However, positive standards for acceptable materials are also a part of these systems
- Monitoring the status: The systems whereby the overall composition of the underwater environment is constantly monitored to determine the status with respect to the standards
- Zonal controls: Processes to determine where certain injections of various types may be emitted and the management controls to assure that no inappropriate injections are made
- Remedial reactions: the ability to neutralize undesirable injection which has occurred; such as the clean-up of major oil spills

DESIRED END RESULTS

The desired end results include the aspirations of those who are operating the generating systems to eliminate their residuals at the most economically feasible manner plus the desires of those who wish to assure effective injection management of the underwater environment.

The desired end results specifically include:

- An economically efficient area within which to dispose of residuals

- A nondegraded underwater environment; i.e., environmental quality
- A "managed" disposal process which enhances the productivity of the underwater environment in three senses:
  - An effective natural disposal system
  - An acceptable dump, i.e., absence of negative results of permitting the ultimate dump concepts to be applied even though the wastes may not be "absorbed" as is the case above
  - A controlled environmental upgrading in which the injections act as nutrients which improve the economic productivity of the underwater environment

GEOPHYSICAL PERSPECTIVES

The impact of injections into the underwater environment is a function of many things: the qualities and types of materials injected, the characteristics and features of the water and/or ocean bottom where the materials ultimately rest, the plant and animal life in proximity to the residuals, and the manner of injection.

From the standpoint of the "unrestricted dump" philosophy there would be no restrictions to injection anywhere at anytime. This philosophy is no longer prevalent. Rather, there are significant restrictions upon injection. These restrictions are to:

- Prohibit uncontrolled injections of some materials; i.e., oil spills
- Permit selective injections in some places at some times for materials (such as radioactive or municipal waste deposit areas)

Although a detailed knowledge of ocean and marine chemistry is still in its infancy, the knowledge is developing rapidly. As this knowledge increases, and as the marine agricultural and other activities discussed throughout this report emerge, selected areas of "waste disposal zones" for various forms of injection likely will be developed.

Present data does not now permit a clear delineation of the geographic features or locations of such zones.

The overall concept of injection is one in which the geophysical limitations are minimal. Such activities can occur virtually anywhere.

TAILORED FORECAST

BASIC CONCEPTS

The basic concepts are discussed briefly below and outlined in Figure 8-2. Further detailed discussion is included in the tailored vignette which concludes this chapter.

Generating Systems

Degree of Societal Response to Recycling Concepts

The level at which total injections are transmitted to the air, land or water reflects a direct functional relationship to the industrial intensity of a society. As discussed previously in both the chapters on Energy and Minerals, the opportunities to vary along this spectrum are considerable. The "industrial intensity" concept has an analogous application to the notion of injection; the critical measure of injection related to the creation or adaptation of recycling concepts, or procedures which curtail or prohibit injection from occurring. The issues can be defined by one of the following basic concepts:

1) World Depository--Some analysts contend that worldwide industrialization supercedes societal concerns for preventing, controlling or regulating injection. From this viewpoint, injection occurs as a result of prior development and favorable management concepts to utilize injection are not perceived.

2) Permissible Injection-- As the potential deleterious consequences of injection has caught the public attention, some have argued that injection should be controlled at point of origin. Thus, injection would not be prohibited but a permissible level of injection would be ascertained and allowed to be emitted.

3) Noninjection concepts--Comprise the array of technological alternatives that exist to prevent, eliminate, curtail, or are used to develop positively managed forms of injections. These concepts foresee injection as a functional component of industrial intensity but seek to capitalize on the economic benefits that injection offers. These concepts are discussed in detail below.

Municipalities

Within the past 10-20 years, catalyzed by both increasing public concern and government regulations, technological alternatives to the disposal of

FIGURE 8-2: TAILORED FORECAST FRAMEWORK: INJECTION OF FOREIGN ELEMENTS FROM MAN'S ACTIVITIES

BASIC TECHNOLOGICAL CONCEPTS	KEY DRIVING FORCES	KEY BARRIERS	OBVIATING FACTORS
Generating Systems • Municipality/Community • Industrial Processing • Dredging Activities • Marine Operations • Others Injection Management Systems • Standards • Monitoring • Zones • Remedial Reaction Desired End Results • Economic disposition of waters • Nondegraded environment • "Managed" Disposal Process	• Increasing municipal/industrial complexes • Naturally occurring transfer of materials from air to water • Increasing use of oceans for transport and exploitation has concomitant increase in offshore industrial operations and vessels • Underlying social values • Population growth • Increasing age of world vessels (tankers) • Increased utilization of nuclear fuel to generate power	• Development of land based disposal systems • Competitive use of ocean • Stricter enforcement of emission standards • New safety mechanisms to prevent accidental leakage and spills • Utilization of alternatives to ocean related resources • Detection systems • Recycling and "total systems" concepts • Economics of developing alternative solid-waste disposal system • Development of new land based energy sources exclusive of petroleum • Potential negative impact on underwater ecosystem	• Development of technology for the total recycling of waste materials

municipal sludge have been developed. The initial attempts to dispose of sewage sludge other than by ocean dumping were based on the premise of "how to get rid of the matter." From this viewpoint, the technological alternatives most commonly employed were incinerator and land-fill mechanisms. Recent full utilization concepts typified by the idea of recycleability and by-product generation has changed this perspective on the disposal of sewage sludge. Recent technological alternatives seek to utilize sewage sludge and, by different processing methods, convert the matter to a soil conditioner or fertilizer of to be used as an energy source for the generation of electric power. New approaches to dumping include ascribing a functional attribute to the dumped material such as using sludge to refill the land in strip-mine regions.

Industrial Processing/Commercial Activities

The injection of industrial residues into the ocean environment can be attibuted to various production cycles and is described as "material" injection. The composite activities of this category are exemplified by the release of heavy metals, organic material and nutrients which often cause eutrophication in coastal waters. The dissipation of heat into the ocean, commonly designated as thermal pollution, though not a specific compound, also constitutes a form of industrial injection.

Alternative methods to dispose of industrial residues include: incineration, landfill, process recovery, and elimination of the material from the production stream.

Dredging/Excavation

Dredging deposits pose a direct problem of disturbing both the physical structure of the ocean bottom and of altering the natural ecosystems that rise in these areas. Present dredging procedures are used primarily as a means for developing ocean lanes, harbors or their navigable waterways. As indicated in Chapter 5 on Minerals, we foresee a rapid acceleration of dredging as a means for mineral extraction and recovery. Dredging operations constitute nearly ninety percent of the total amount of wastes that are directly dumped into the ocean. Therefore, what previously has been a significant source of injection should escalate. Alternative approaches to the disposal of dredged spoils are only in their infancy of development, with land refill the current most likely alternative. Basic research that analyzes the impact of disturbing the ocean bottom should lead to new economic and environmental approaches.

Marine Operations

Injections that originate from marine operations may occur from the transportation of materials which are accidently emitted into the ocean from normal functioning of vessels often requires discharge of oil or bilge into the water; and from the whole panorama of offshore industries which, like their land counterparts, inject residues as a runoff of their daily operations.

Included in this section are all military activities which may inject material into the ocean, such as target practice, munition seepage, and weapons testing.

Other

The injection of radioactive wastes and the dispersal of material that is derived from the combustion of fossil fuels are two forms of ocean injection which cross the category delineation presented above and are thus separated out to indicate their pervasiveness in the whole injection picture. Radioactive wastes may be injected into the ocean from a variety of sources including atmospheric testing of nuclear weapons, nuclear power plants, leaks from sealed containers of radioactive wastes or by accident such as the sinking of nuclear-powered ships. Hydrocarbon residuals from fossil fuel combustion are transmitted into the ocean via the atmosphere.

Injection Management Systems

Injection management systems are comprised of those operations which dictate the level of permissible injection, those operations which determine the specific type and concentration of injected matter, and those systems which seek to isolate or control the dissipation or injection. These specific management processes are discussed below.

Designation of Standards

The designation of standards has been developed almost exclusively for control of injection, neglecting concepts which would promote injection of acceptable materials that have positive effects on the ocean environment. Many recent evaluations on parameters incorporated into standard setting have reflected that scientific ignorance about ocean processes and functions is pervasive. The ocean attributes or mechanisms that should be involved in standard setting consist of the following:

1) Chemical baselines--A determination of the chemical composition of the constituents of the ocean, their susceptibility to absorbtion in biological systems, the physiochemical reactions of each component.

2) Biological baselines--An evaluation of absorption rates on life forms ranging from microorganisms to higher life forms. An understanding of the intricate "balance of nature" within ocean systems, so that if a low level species is disrupted, a higher organism likewise will be affected.

3) Physical baselines--the diverse attributed of oceans that include salinity, temperature, currents, depths etc. and how injected matter is transported and dispersed by these physical events.

Apart from the ocean parameters needed for standard setting, the rates of transmission from the generating systems must be carefully ascertained. This phase poses unique difficulties for measuring subliminal injections such as run-offs or atmosphere transfer in which the generating source is not a tangible or physical entity like an industrial production facility.

Monitoring Systems

A comprehensive monitoring system will utilize the assay methods and research tools that delineate the chemical, physical and biological baselines required for standard setting. Monitoring of the ocean can occur from direct measurements of ocean properties, or by indirect sensing techniques. The variety of approaches are capsulized below.

Air to Water Techniques--Incorporate all weather forecasting methods that potentially could be utilized to trace the transmission of materials from the air to the ocean. Satellite tracking of storm systems, wind direction measurements and air particle density measures, comprise the type of instrumentation that is presently utilized and would have direct application to a total injection monitoring system.

Water Property Measurements--Comprise the systems that assay the chemical composition of the water. Potential systems include the concept of passive stations, such as floating buoys located throughout the world, that have built-in analysis capabilities to determine the properties of the water, transmit the results of their findings to a centralized computer for final analysis. Water measurements can be done in a simpler manner by taking a sample from the ocean and analyzing it on a vessel or in a land facility.

Biological Sampling--As indicated in the previous section, biological organisms provide a clear gauge that injection enters living species and the food chain.

Zonal Concepts

Zonal controls employ all methods required for the designation of certain areas where injections are permissible or restricted. Currently, the dumping of industrial wastes represents one type of zone concept. The objective of this type of disposal is to eliminate the consequences that the waste imposes on land life, and to decrease its impact on the marine environment by depositing in an isolated area. Other zone concepts include:

1) Temporary restrictive zones--imposed for short term mostly in response to an accident such as a major oil spill. The objective is to present the spread of the injected material and to lessen any potential dangerous impact the material could have on human life.
2) Permanently damaged areas--In which the accumulation of the injected material poses a long term danger to human and marine life. Areas in which radioactive material has leaked and are now restricted for other marine usage
3) Marine supplication--The planned injections to stimulate marine growth or in some other manner enhance the quality and productivity of the marine environment
4) Environmental purity--Areas designated for the preservation of pure water and a clean environment such as would be required for underwater recreational parks

Remedial Reactions

Remedial reactions are those procedures that are used proactively to neutralize the impact of an undesired injection on the marine environment. Primary research efforts in this general area, devoted to the cleanup of oil spills, poses the most visual and significant short-term negative impact on marine ecology. The basic methods employed for oil spill cleanup will have analogous applications to other injections. These general or remedial measures include:

- Mechanical containment techniques which encumber and prevent the dispersal of injected matter. These barriers could be physical structures such as floats or some chemical mechanisms which restrict free movement of the injection
- Sinking procedures are designed to remove the threat of injection in an expeditious manner by preventing the injection from occuring or continuing. For example, if an oil vessel

splits in half from a severe storm, part of the oil may be in containers that have not been split apart. By sinking the remains of the ship the sealed containers will reside on the ocean bottom and not be subject to further rupture

- Chemical dispersion methods act like conventional soap or detergent. These procedures break up the injected matter into small particles

- Physical absorbtion techniques are designed to remove the injected matter in a similar way a sponge is used to clean a countertop. Some material is placed in the area where injection has occurred and when the matter is removed it takes the undesired material with it

- Combustion is employed to burn off the injected material

- Biological degradation techniques utilize microorganisms which eat upon the injected matter and retard its dispersal

TAILORED VIGNETTE

Continued industrial growth and municipal expandsion will create a direct increase in the total amount of injected matter into the ocean the immediate short term. Irrespective of the development of control systems or adaptation of alternative technologies, the input of undesired material into the ocean will escalate as the number of generating systems increase. This forecast incorporates the ideas previously stated in Chapter 4 on Energy that society will chose a specific course of continuing energy intensity. The expanding concentration of urban centers will intensify the problem of disposal of sewage wastes and other matter that originates from human activity. These events set the stage for rising levels of injection into the ocean. The specific sources of injection will include all phases of petroleum production, from early exploration, through extraction, transportation and refinement: the emission of chemicals which result from the combustion of fuels, particularly from automobiles, and dredge spoils from excavation sites and mining locales.

Ocean injection will continually be perceived as a problem or a pollution in this phase of rapid development and industrial expansion. Governmental guidelines will be established to improve equipment design and to curtail overall injection levels. New comprehensive systems of detection will tend to magnify the issue of injection; previously undetected material will be isolated and the pervasive manner in which injected matter can be transmitted through the marine life cycle system will be determined. Initial industrial response to both public pressure from marine-oriented environmentalists and the state and federal governments will be to develop systems that curtail the total output of residues. This objective will be met by the utilization of recycling concepts. *The increasing threats that injected material pose on marine life and human life will activate the creation of a variety of methods to neutralize the presence of the injected material and to counteract its harmful effects.* The injection of material into the ocean will increase feedback and impact on human life and food systems. Fishing capabilities will be impared by the detection of newly identified material in fish and other marine species. The issue of radioactive waste disposal and associated dangers to marine life will also catalyze programs which seek to neutralize the effects of material injected into the ocean. The dumping of wastes generated by human activity, principally the disposal of sewage, will not

be satisfied by the development of alternative land disposal systems, for they will be restricted by the high cost of design and development, and because their use will be curtailed by their failure to meet air and water emission requirements. In some cases, alternative systems will still feed injections into the ocean such as land fill utilization in which the potential for runoffs clearly exists.

The initial management concepts employed to counteract injections will be one of neutralization. This means utilizing whatever mechanical, chemical or biological systems that will tend to lessen the impact of identified dangers from injection. The objective of neutralization methods will be to insure that the quality of the marine environment remains in the same state as it was prior to injection. Mechanical neutralization techniques will encompass all methods that utilize some hardware or instruments to physically remove the injection from the ocean. Present day oil skimmers used for oil spills typify this concept. In the future a variety of mechanical devices will be employed for diverse types of injection. Chemical agents that dissipate injected material will be developed. These chemicals will function so that the injected matter reacts in some form as to eliminate its impact on the marine environment. Biological agents will include the adaptation of microorganisms that feed upon the injected matter. The combined effect of these neutralizing concepts will be to allow coastal municipalities and some industries the opportunity of achieving a cheap waste disposal system. *By the mid 80's the concept of positive management will be articulated formally and the basic research and selective concept will be initiated.*

Positive management concepts, the injection of materials into the marine environment to enhance or augment the quality of the marine life or to develop some form of economic productivity, will stem from a converging set of variables. Initially, injection as pollution will be a key operation concept. This idea then will stimulate neutralization, which in turn will be expanded to suggest economic productivity. The final step will be derived from the preception that marine environment has numerous possibilities of resource development and economic growth opportunities. The neutralization concepts which lead to a cheap selection alternative waste disposal system will catalyze ideas of economic opportunity that are not forms of resource extraction alone. (It should be noted that ocean extraction refers to the direct removal of some components or raw material from the marine environment that has value, i.e., fish, minerals, etc.).

CHAPTER 9: INJECTION OF FOREIGN ELEMENTS FROM NATURAL FORCES

DEFINITION

Injections that occur naturally without the intervention of any human activity are represented in this category and distinguished from the forms of injection that were previously discussed. The origin of natural injection into the marine environment are often less visible than those that are a product of man's activity. As stated before, injection does not connote positive or negative impacts and specifically avoids suggesting that disruptions are of a harmful nature.

Unlike man-initiated injections which can be deliberate, accidental, subliminal, or managed in scope, natural force injection occurs completely without the element of human control and in some forms can be called accidental. Natural injections presently are best exemplified by oil seepages from the ocean bed. The specific activities defined within this category vary depending upon the source. The activity delination includes:

1) Natural Seeps and Leakages
2) Injection as a result of natural forces
3) Injection from marine species

BACKGROUND

Present known leakages from the ocean bottom are the most visible and apparent type of natural injection. Natural gas leakages have also been identified when exploration for oil has occured. Some estimates indicate that natural seeps account for nearly ten percent of the total amount of petroleum hydrocarbons transmitted to the oceans.

Injection from natural forces include the deposition of matter into the ocean as a direct result of a natural event. For example, the atmospheric transferring of materials emitted from volcanoes into the ocean, ocean bottom matter lifted and redeposited from a hurricane or severe storm, or the surfacing of material from the ocean floor after an earthquake.

Injection from marine species include the net residues that are transmitted to the ocean as part of their waste function. Thus far, there has been no identification of this area as a potential concern for accumulation.

FUNCTIONAL SYSTEM

The basic functional system involves a set of activities which generate injection materials, management systems which in some way manipulate the matter and end-fate systems. The basic functional system for natural sources is similar to the previously discussed framework for injection by man's activities. However, unlike injection derived from man's activities, which at times can be controlled at the point of origin, natural injection is solely by accident and presently can not be controlled. Nonetheless, the functional system incorporates those concepts that ultimately may be developed and utilized to manage natural injection. As is seen in Figure 9-1, each of the general components is comprised of a series of sub-systems.

FIGURE 9-1: FUNCTIONAL SYSTEM: INJECTION FOREIGN ELEMENTS FROM NATURAL SOURCES

Generation Source	Management Systems	End-Fate
Leakages and Seeps	Neutralization Methods	Non-degraded underwater environment
Natural Force Residue	Monitoring Systems	Managed Processes
Marine Species Residue	Zonal Controls	
	Remedial Reaction	

Generation Source

The generation sources include:

- Residuals which are deposited or injected into the underwater environment as a result of natural leakages or seeps. This material normally comes from cracks in the earth's crust below the ocean bottom
- Residuals which are the result of natural forces. These deposits include air-to-water transmission of volcanic waste, hurricanes, tsunami or any other natural event which carries new material into the ocean
- Residuals from marine species are the wastes injected into the ocean as a result of normal marine life functions

Management Source

The management systems for natural injection overlap with those for injection from man's activities, and include the concepts of standard designation, monitoring, zonal control and remedial reactions. However, greater emphasis must be placed on those concepts that employ neutralizaiton techniques for

the often unanticipated nature of natural injection decreases the probability of controlled management. For a complete review of the management system see page 5 of Chapter 8.

End Fate

The end fate of injection reflects the desired objection in the quality of the marine environment. The spectrum ranges from noncontrolled (any injection is permissible) to the positive management concept introduced in the last chapter.

TAILORED VIGNETTE

The natural phenomena that initiate injection into the ocean will continue to occur and the natural and physical methods which transport injection will remain. The above statement simply states that the world's physical forces and marine life will continue to exist throughout the forecast period. We do not foresee significant technology advances that would preempt a major natural event from developing.

Monitoring systems and detection capabilities will enhance the likelihood for predictive capabilities of major natural phenomena and isolate new locations of natural seeps. Scientific research into the whole domain of underwater activities will escalate as a direct by-product from operationalization. Weather forecasting systems, earthquake predition methods and mineral resouce identification will be key factors that provide foundational information on natural force occurrence within the underwater

The initial management concepts employed to counteract injections will be one of neutralization. This means utilizing whatever mechanical, chemical or biological systems that will tend to lessen the impact of identified dangers from injection. The objective of neutralization methods will be to insure that the quality of the marine environment remains in the same state as it was prior to injection. Mechanical neutralization techniques will encompass all methods that utilize some hardware or instruments to physically remove the injection from the ocean. Present day oil skimmers used for oil spills typify this concept. In the future a variety of mechanical devices will be employed for diverse types of injection. Chemical agents that dissipate injected material will be

developed. These chemicals will function so that the injected matter reacts in some form as to eliminate its impact on the marine environment. Biological agents will include the adaptation of microorganisms that feed upon the injected matter. *By the mid 80's the concept of positive management will be articulated formally and the basic research and selective practices will be initiated.*

Positive management concepts, the injection of materials into the marine environment to enhance or augment the quality of the marine life, or to develop form of economic productivity, will stem from a converging set of variables. Initially, injection as pollution will be a key operation concept. This idea then will stimulate neutralization, which in turn will be expanded to suggest economic productivity. The final step will be derived from the preception that marine environment has numerous possibilities of resource development and economic growth opportunities. The neutralization concepts which lead to a cheap selection alternative waste disposal system will catalyze ideas of economic opportunity that are not forms of resource extraction alone. (It should be noted that ocean extraction refers to the direct removal of some components or raw material from the marine environment that has value, i.e., fish, minerals, etc.).

The positive management concepts and neutralization techniques developed primarily for injection by man's activities will have spin-off application in the area of natural injection. Concepts will be developed for selective "manipulation intervention" with the natural forces as a way to preclude their injection. These techniques will be applied only on a highly selective basis, and only to a very modest degree within the forecast period. For example, if a volcanic eruption is about to occur, and if it is closely situated to oil fields or other areas of economic or marine activity, efforts will be made to apply any potential techniques to divert or control such an eruption. During the forecast period natural force preemption or neutralization will remain on a low level of research activity and in an experimental stage.

CHAPTER 10: RECREATION/CONSERVATION

In many respects conservation is an inherent component of the other activity categories. For example, nondegradation of the quality of the marine environment from pollutants (discussed in Chapter 8) is a form of conservation. The particular type of conservation discussed in this chapter is confined to the designation of certain areas specifically set aside, or retained in something close to their natural or unique state. In general, recreation is activity whose marine-related principle purpose is to offer persons a time and place for leisure, pleasure, and enjoyment. Most recreation occurs through boating, diving, and fishing. That form of recreation is discussed briefly in Chapters 6 and 7.

The specific activities which are included within this category are:

(1) Production of specific marine species which are in danger of extinction, and which are not included within the concepts of marine managed agricultural organisms.

(2) Preservation and protection of critical habitats in the marine/estuarine ecosystems, e.g. coral reefs

(3) Operation of recreational national parks and seashore areas

(4) Protection of unique points of interest to assure the continuance of singular cultural and historical features, such as historic shipwreck sites, underwater caves, unusually beautiful coral reefs, and other geological treasures or exotic plant/animal habitats

(5) Protection of various areas for other reasons, including the designation of areas for specific research purposes, for aesthetic purposes, for assurance of nondisruption of important ecological forces such as iceberg areas, etc.

Recreation and conservation often are highly complementary activities. For example, the land wilderness areas also are very popular recreational areas for camping, hiking and other outdoor recreational pursuits.

Both conservation and recreation activities may have important commercial implications. It is common to perceive the recreation industry as an economic sector which facilitates the use of a given area (in this case the underwater environment) for the purposes of pleasure, relaxation, and leisure.

Many areas meet more than one of the above definitional criteria. The site of the wreck of the U.S.S. Monitor, for example, meets the criteria for 3 and 4. The coral reefs off Florida's Key Largo meet 1, 2, and 3.

BACKGROUND

As human activity within the offshore environment has increased, concern has grown for both the recreational opportunities which it can afford, and the conservation of certain resources within this environment. Concepts of marine/underwater parks and sanctuaries have gained considerable priority only recently. Most of the over 150 marine parks throughout the world were so designated within the past fifteen years. In May 1975, during the International Conference on Marine Parks and Reserves in Tokyo, the Cook Islands established the first World Marine Park at the island of Manaue, a small coral island of about eight square miles.

Within the United States and her trust territories, there are:

- Over 30 designated marine/seashore parks, of which about one-third are located in the Pacific including the West Coast, off Alaska, Hawaii, and the Pacific Trust Territories; 5 in the Great Lakes region; and the remainder spread along the Atlantic and Gulf Coast States (including two in the Caribbean Territories)
- Two officially designated marine sanctuaries, the Key Largo Coral Reefs Sanctuary off Florida protecting a 100 square mile coral reef area, and the Monitor Marine Sanctuary designed to protect the wreck of this Civil War ironclad (an area of about 1 mile in diameter)
- Only one area of the U.S. National Park System has been specifically recognized as an "underwater park," the Buck Island Reef National Monument in the Virgin Islands. Buck Island offers underwater trails demarcated especially for visiting tourists/divers. Other parks have offered or have considered offering trails such as these, but the cumulative rate of usage thus far has not warranted the expense of maintaining trails in these other parks.

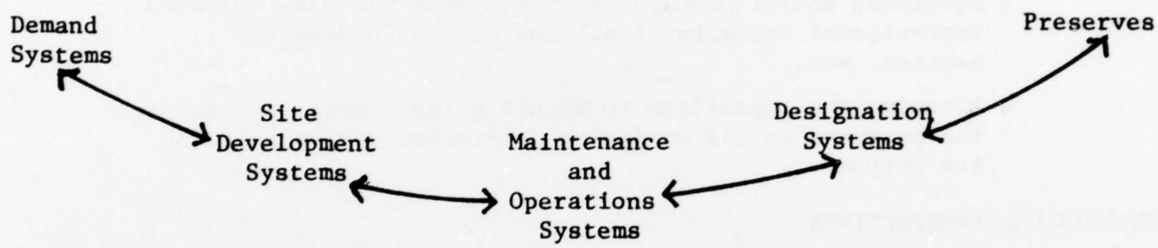
As the diverse network of social, economic, political, and technological developments related to the marine/underwater environment come into view, much greater attention will be given to preserving and conserving our marine ecosystem and the resources within it. Comparatively large marine areas will be given consideration for designation as parks and/or sanctuaries, a pattern similar to the historical features and pace of the U.S. land "wilderness" concept. Furthermore, the array of technologies developed for marine/underwater commercial activity such as offshore production of oil and gas, seabed mineral mining, and so forth will have positive spillover effects for the recreation

area. The inventory of these technological devices and techniques is quite lengthy, and is discussed throughout this report. Despite the fact that many present recreation related activities are not economically justifiable, they will become economically feasible as the front-end costs are expended in those more fruitful commercial ventures in the marine/underwater environment.

FUNCTIONAL SYSTEM

The functional system for recreational/conservation preserves is outlined in Fugure 10-1.

FIGURE 10-1: FUNCTIONAL SYSTEM: UNDERWATER RECREATIONAL/CONSERVATION PRESERVES



Demand systems usually involve one or more of the following:

- Groups who wish to protect some particular aspect of the natural marine environment
- Groups who wish to develop the underwater recreational potentials as a commercial venture
- Groups who wish to "consume" the underwater natural and recreational features

The preserves which are emerging generally include the following basic types:

- Selected marine species (animal and/or plant) sites
- Critical habitats preserves
- Recreational, aesthetically unique or appealing locations
- Unique points of historic or natural interest
- Natural preserves to be retained for scientific/conservation purposes

These preserves are determined by a complex process of interacting demands and knowledge of marine/underwater features. These processes are termed "designation systems." These systems include:

- Detection/inventory of underwater features
- Procedures for formally designating the site, including the rationales for such restricted useage
- A final jurisdictional assignment of the designation

Perhaps the most difficult aspect of the designation process originates with conflicts of use. When any preserve is specified, it immediately restricts many other possible activities such as waste disposal, transportation, commercial offshore exploitation, marine transportation, and in some instances, even recreational activity

Site development systems include the technologies and delivery procedures for any clean-up, construction or other facility requirements which the preserve will need to fulfill its designated purpose.

Maintenance and operating systems include:

- Retaining and/or perhaps initiating and managing selected recreational activity, i.e., the diving, underwater habitat, etc.
- Assuring the capability to maintain the overall status of the preserve in the condition determined appropriate for its purpose

GEOPHYSICAL PERSPECTIVES

The siting and designation of marine/underwater recreation and conservation parks and sanctuaries theoretically can occur wherever the protection and preservation of certain marine resources and ecosystems is assessed as needed. If a particular historical landmark or marine species is adjudged to be worthy of preservation or protection, the site of this landmark or habitat area of the given species alone would determine its designation regardless of specific geophysical perspectives within the area determined in need of preservation and protection.

In spite of the seeming irrelevance of geophysical perspectives for some conservation/protection/preservation sites, geophysical perspectives will emerge as important criteria for the designation of recreational sites. We would assume, for example, that a selected recreation park would offer:

- Relative freedom from unhealthy pollution levels
- Save distance from frequently travelled ocean lanes/transit
- Distance from various offshore economic activity such as floating or fixed pile oil and gas production platforms
- Reasonably calm, warm waters
- Comparatively close to large land-based populations who could traverse to such park facilities within a reasonable time

BASIC CONCEPTS

Recreation/conservation preserves and the related activities within these sites entail a complex network of concepts important to the future rise or decline of these preserves. We have highlighted some of these concepts while discussing the functional system for preserves (see Figure 10-1); however, this brief section was not intended to be all-inclusive when assessing the potential alternative futures for preserves. The following basic concepts and the components within each, need to be assessed to assure comprehensiveness and validity for our tailored vignette:

Demand Systems

Many diverse societal needs will determine the scope and application of recreation/conservation preserves--for instance:

- Need to protect the marine/underwater environment and the resources found within it
- Need to conserve the marine/underwater environment and the resources within it
- Demand to participate in or "consume" the pleasures associated with the marine/underwater environment
- Demand by commercial/recreational industry to develop the marine/underwater environment as a profit venture
- Need to better understand the unique scientific features of the marine/underwater environment

Functional Systems

Each marine/underwater park, seashore, and/or sanctuary serves one, and perhaps more, specific functions to satisfy the above demands/needs. Some of these functions would include:

- Protecting selected environments
- Preserving or conserving selected environments
- Providing selected environments for a growing recreation, leisure-oriented sector, or for an inquisitive scientific research

Designation Systems

In order for a given marine/underwater site to become a jurisdictionally recognized and protected preserve, each site must undergo a number of processes to assure legal designation and protection. These processes might entail:

- Initial siting for further inquiry
- Specific scientific/biological/historical investigative inquiries
- Proposals to specific jurisdictional bodies capable of assuring recognition and protection of the selected site.
- Assessments of the above investigative findings vs. functional needs
- Assessments of needs vs. impinging/competing conflicts in uses of a selected site area
- Key debates, conferences, and other avenues of discussion to resolve issues stemming from any contradictory assessments determined above
- A proclamation depending on the outcome of the above processes, refusing or granting a jurisdictionally preserved, protected, and/or conserved site.

Impinging Conflict Uses

Although conflicting uses of selected marine/underwater environments are discussed partially above, the salience of these concepts to the actual designation and/or continuing operation of a preserve demand some further explication. Some of the potential conflict uses of any given area might include:

- Key waste disposal systems/facilities for comparatively small to large population centers.
- Important waters for the uninterrupted flow of trading ships and vessels
- Offshore/underwater commercial exploration, exploitation, and operations, e.g., oil and gas extraction and gravel mining dredging
- Various other potential uses, e.g., key waters for commercially netted fish stocks, or areas traditionally set aside for naval operations

Maintenance and Operations

Once a preserve is designated, its functional role clearly defined, and the competing conflict uses/issues resolved, numerous personnel, procedures, and technologies must be employed to assure the protection, preservation, or conservation of the site. For instance, a protected marine/underwater habitat for an endangered species requires that authorized personnel be at the site to assure no violations will occur; these personnel will require support craft and diving equipment for patrol duty; monitoring equipment will be needed to assure the protected environment and the resources within it are retained in the condition originally sought.

KEY DRIVING FORCES, KEY BARRIERS, AND OBVIATING FACTORS

Figure 10-2 outlines the driving forces, barriers, and obviating factors relevant to forecasting underwater recreation/conservation-related activity. In the following tailored vignette, we highlight many of these forces, barriers, and factors which ultimately will determine the scope and application of underwater parks, national seashores, and protected marine sanctuaries.

FIGURE 10-2: TAILORED FORECAST FRAMEWORK--
RECREATION/CONSERVATION PRESERVES

BASIC TECHNOLOGICAL CONCEPTS	KEY DRIVING FORCES	KEY BARRIERS	OBVIATING FACTORS
Demand Systems (see page 10-5) Functional Systems • To protect • To preserve • To provide Designation Systems • Initial siting • Scientific/other inquiries • Proposing sites • Legal assessments • Conflict use assessments • Refusal or granting Impinging Conflict Uses • Waste disposal systems • Trade routes • Commercial activity • Military operations • Other *Maintenance and Operations* • Personnel • Support equipment	• Growing need to preserve/conserve resources in danger of extinction • Desire to protect selected resources and environments from uneven exploitation or unnecessary "overkill" • Increasing desire to preserve unique points of national and/or historic interest • Rising demand for more recreation areas to view and/or participate in underwater domain • Existence and readiness of commercial enterprises to undertake selected recreation-oriented investments/ventures • Societal/scientific willingness to study the marine environment in order to better understand the living and non-living resources within it	• Impinging, diverse conflict uses • Frequently lengthy regulatory environment; other related bureaucratic delays	• Significant decline in societal interest in preserving or protecting key areas • *Impinging conflict* uses obviate feasibility of setting aside selected areas for protection or preservation

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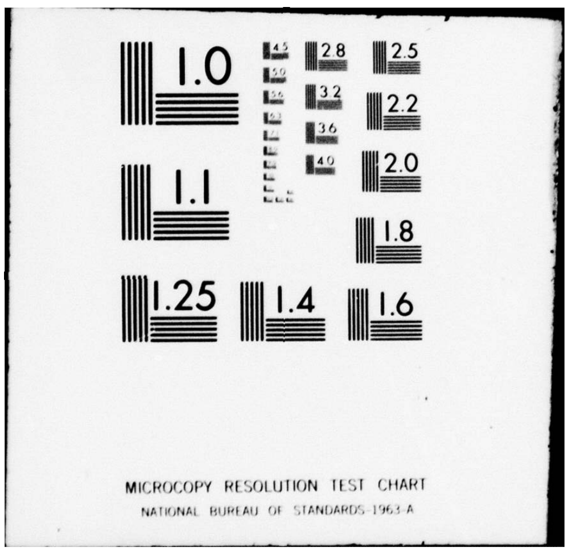
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THE TAILORED VIGNETTE

Despite rapidly increasing offshore commercial activity, the nation's interest and concern in preserving and protecting selected areas of the marine/underwater environment will remain intact. We can expect lengthy debates to take place during the next decade between proponents stressing accelerated offshore commercial exploitation and groups and individuals insisting on strict controls, and in some cases, total bans on all human activity offshore. Most of these divergent opinions will focus on regions found in offshore sunbelt portions of the U.S., e.g. the southest Atlantic, the southern West Coast, and Hawaii. Compromises between proponents and opponents of increasing offshore economic activity will emerge. Many offshore areas will be selected for commercial exploitation, especially where economic priorities/realities far outweigh potential environmental disruption. In contrast, many areas will be set aside for protecting and/or preserving living and/or nonliving marine resources. The implementation of effective, efficient monitoring and management systems will be essential for both types of designated areas in order to:

- Determine, on a continuing basis, the exact effects of dumping, commercial and recreational fishing, offshore mineral exploration and extraction, etc.
- Assure that those areas intentionally set aside for protection and preservation of resources do not become victims of further exploitation, looting, or other types of violations

Before the end of the next decade, a major national program will be set in motion to more intensely identify, inventory, assess, and continuously monitor our marine/underwater environment. Expanding population along the coastal margins and the increasing demands these inhabitants will put forth for more coastal recreational sites and facilities coupled with the overall willingness of the leisure/recreation economic industry, will assist in precipitating and carrying through such a program. The leisure industry gradually is becoming a more important economic sector in the U.S. The ability of this sector to successfully lobby for greater investment opportunities will advance significantly. Indeed, this sector is likely to share much of the costs associated in implementing and developing this national program involving marine/underwater parks, seashore sites and related facilities, and regulated sanctuaries.

We foresee the designation and stringent protection and preservation of hundreds of marine/underwater parks and sanctuaries by the year 2000. At least 15, and perhaps as many as 25 such preserves will be located in U.S. territorial waters. Currently, a number of nations (Canada, Japan, Kenya, the Phillipines, Denmark, as well as the U.S.) are leading what appears to be a gradually evolving international effort to protect and preserve key marine living and nonliving resources. This trend will continue. Within the U.S., a multitude of proposals already have been submitted to public officials requesting certain marine areas be designated sanctuaries to assure the preservation of unique habitats and the life which resides in this environment. It is unlikely that most of these proposals will be accepted. Yet further analysis and assessments of areas along coastal margins will determine a host of locales where severly threatened marine resources exist, and need to be preserved. Generally, these sites will be designated in comparatively remote marine/underwater environments. Many protected sanctuaries will prohibit practically every kind of commercial/recreational inhabitants.

Marine/underwater protected and preserved areas will be developed and operated by both the public and private sector. The specific function of the site will determine which sector is the predominant operator. Parks and sanctuaries with unusually sensitive features generally will be monitored and protected closely by the public sector. Where severely threatened marine living and nonliving resources are found, it is most likely that state, local, or federal officials and patrols will bear the brunt of development and protection activity. Strict regulations and bans in these areas are likely to limit commercial activity, tourism, and perhaps even sightseeing. As a result, little, if any, income will be derived from these sites. Private investment in a venture such as this will be minimal, and probably limited to occasional contributions.

In contrast, underwater parks, seashore sites, and conceibably some sanctuaries not requiring a stringent regulatory environment will be developed and operated by the private sector. These sites will be located near heavily populated coastal centers in comparatively warm climates. Monitoring of the effects of recreation and commercial activity in particularly sensitive areas will continue to be undertaken, predominently by public sector officials; enforcement of specific regulations also will remain in the hands of government patrols. Nonetheless, commercial enterprises will seek broad development rights in these sites. Ongoing restraints on surging public sector expenditures during

this period will prohibit extensive governmental involvement. The public sector is likely to request commercial enterprises to make purchase bids or perhaps even lease some sites before a large-scale recreational development effort may occur.

Before the turn of the century, we can expect as many as 100 or more recreation-oriented seashore, marine, and underwater parks to be in total operation. Most of these sites will offer only a minimal amount of tourist attractions other than the natural beauty of the site. Nonetheless, there will be a handful of parks which provide:

- Extensive sub-sea trails demarcated for visiting divers
- Underwater restaurants and/or hotels aimed principally at permitting tourists to view marine resources while eating or relaxing
- Structures specifically constructed for tourists to observe underwater phenomena, perhaps through portholes or large sub-sea rectangular windows.
- Glass-bottom boats for sightseeing tours
- The use of a few submersible tourist vehicles with ample viewing posts for riders

Near or after the year 2000, the growing recreation industry will explore seriously the feasibility of constructing a completely autonomous underwater recreational park facility. Although designs and conceivably partial construction of such a concept will be under way before 2000, we do not expect application or operation of this type of facility during the forecast period. Suffice it to say here that it probably would offer accomodations for no more than 50-100 persons at one time, and that the expense to interested tourists initially will be non-competitive with counterpart leisure accomodations on land.

FIGURE 10-3: TAILORED VIGNETTE - RECREATION/CONSERVATION

POTENTIAL DEVELOPMENTS	PROBABILITY/TIMING		
	1981-85	1986-92	1992-2000
PUBLIC INTEREST AND CONCERN IN PRESERVING/PROTECTING SELECTED MARINE/UNDERWATER ENVIRONMENTS REMAINS INTACT	H	H	G
• NUMBER OF DEBATES TAKE PLACE BETWEEN PROPONENTS AND OPPONENTS OF INCREASING OFFSHORE COMMERCIAL EXPLOITATION	H	H	G
• COMPROMISES WILL ENTAIL AND REQUIRE THE IMPLEMENTATION OF EFFECTIVE AND EFFICIENT MONITORING AND MANAGEMENT SYSTEMS	G	H	H
- TO DETERMINE HARMFUL AND DANGEROUS EFFECTS OF SELECTED COMMERCIAL ACTIVITY	G	H	H
- TO ASSURE KEY AREAS ARE PROTECTED FROM FURTHER EXPLOITATION AND PRESERVED IN THEIR NATURAL STATE	G	H	H
MAJOR NATIONAL PROGRAM SET IN MOTION TO IDENTIFY, INVENTORY, ASSESS, AND MONITOR UNDERWATER ENVIRONMENT	G	H	H
INCREASING NUMBER OF MARINE PARKS/SANCTUARIES DESIGNATED AND STRINGENTLY PROTECTED BY HOST OF NATIONAL GOVERNMENTS IN THE WORLD COMMUNITY	H	H	H
NUMBER OF SANCTUARIES WITHIN THE U.S. RAPIDLY INCREASES	G	H	H
• GENERALLY FOUND IN REMOTE MARINE/UNDERWATER LOCATIONS	G	H	H
• PROHIBIT MOST COMMERCIAL/RECREATIONAL ACTIVITY	G	H	H
PROTECTED/PRESERVED AREAS WILL BE DEVELOPED AND OPERATED BY BOTH PUBLIC AND PRIVATE SECTOR	L	G	H
• SEVERELY THREATENED AREAS WILL BE DEVELOPED MAINLY BY PUBLIC SECTOR	H	H	H
• PRIVATE SECTOR RECREATIONAL INDUSTRY WILL DEVELOP SITES WITH HIGH TOURIST TURNOUT AND APPEAL	L	G	H
AS MANY AS 100 RECREATION-ORIENTED SEASHORE, MARINE, AND/OR UNDERWATER PARKS WILL BE DESIGNATED AND OPERATING	M	L	H
• MOST SITES OFFER MINIMAL TOURIST ATTRACTIONS OTHER THAN NATURAL BEAUTY/AESTHETICS OF AREA	H	H	L
• SOME SITES OFFER EXOTIC, UNIQUE FEATURES FOR TOURISTS	M	L	G
- SUB-SEA TRAILS FOR DIVERS	H	H	H
- UNDERWATER RESTAURANTS/HOTELS	M	L	G
- UNDERWATER OBSERVATION STRUCTURES	L	G	H
- GLASS-BOTTOM BOAT TOURS	L	G	H
- TOURS ON SUBMERSIBLE CRAFT WITH AMPLE VIEWING POSTS	M	L	G
RECREATION INDUSTRY EXPLORES SERIOUSLY FEASIBILITY OF UNDERWATER RECREATIONAL PARK FACILITY	M	L	G
• DESIGNS INCLUDE SELF-SUFFICIENCY FOR LONG PERIODS OF TIME WITH ACCOMODATIONS FOR 50-100 PERSONS	M	L	G
• BECOMES TOTALLY OPERATIONAL	M	M	L

M = minimal **G = good**
L = low **H = high**

CHAPTER 11: SCIENTIFIC RESEARCH

DEFINITION

Scientific research comprises all investigations into marine life, the ocean and its properties, and operational and engineering aspects of the subsurface which in some way increase the overall body of knowledge on the underwater and facilitate the development of specific underwater activities. The scope of scientific research expands all known scientific disciplines and includes new disciplines that are being generated by the expanding studies of marine life and the oceans.

This chapter is not a compilation of all major research endeavors that exist, will exist, or will be required. Rather, the objective of this section was to review current research programs in juxtaposition with the forecasted activities and outline major areas of congruency. This approach facilitated the development of general areas of scientific inquiry and the forecast of events within these topics. The topical areas of research represent our activity listing for this chapter and include:

- Inventory of the earth's resources and ecological systems
- Meteorological relationships
- Physical forces (tides, currents, etc.)
- Physical chemistry compositions and dynamcis
- Geological/geophysical phenomena and dynamics
- Marine life systems and higher organisms
- Marine plant systems
- Human organisms in undersea environments
- Engineering technologies/systems for underwater operations
- Resource development and management
- International geopolitical issues and resolutions
- Other marine management issues
- Other scientific and research activities

BACKGROUND

Marine scientific research can be traced back to the early Greek postulations on ocean phenomena, through the earliest uses of navigational aids in the 13th century, up until the present conquest of the underwater. Historically, the

ocean has always caught man's interest; scientific inquiry has advanced in close conjunction with the level of marine activity.

The present research structure of the ocean is represented by a large number of diverse and often competing characters. For example, many agencies of the U.S. government conduct or sponsor some type of marine research, yet the mechanisms to disseminate results and preclude overlapping or repititive studies are not strongly organized. In addition, private research institutions, industrial groups and international organizations are all active participants in the marine environment.

Future marine research will be set against a complex background of technological advances and management policy decisions which will tend to shape the level at which scientific research in the underwater develops. Among these issues will be:

- The establishment of various groups to coordinate marine research and development either on a national or international level. Mechanisms which promote research results could catalyze new endeavors into projects that were overlooked or had not been created.
- The advancement in underwater equipment designed specially for operational usages may have spinoff impacts on scientific research, or the converse situation could evolve. Material and equipment advancements from space engineering may find increasing adaptability in the marine environment.
- The advent of a variety of underwater activities in areas of common usage will foster sea zone plans and management policies to yield ideally the highest level of economic utility.
- The activity push, for example, the desire to mine nodules, may accelerate the required knowledge to implement or operate an underwater event.

FUNCTIONAL SYSTEM

The functional system comprises three major components: the demands that society has for scientific research of the underwater, the generalized areas of investigation that exist about the unknown phenomena of the ocean, and the research systems or instruments of inquiry which bridge these two other areas.

As is seen in Figure 11-2, each of these general components consists of a series of subcomponents.

FIGURE 11-2: FUNCTIONAL SYSTEM: SCIENTIFIC RESEARCH

DEMANDS FOR SCIENTIFIC RESEARCH	RESEARCH SYSTEMS	PHENOMENA OF THE OCEAN
Operational Needs	Institutions	Properties of the Ocean
	Instruments	Marine Life
Nature of Scientific Inquiry	Human Resources	Engineering Concepts
		Management/Zone Issues

DEMANDS FOR SCIENTIFIC RESEARCH

1. Operational Needs - To conduct or implement underwater activities basic research requirements must be fulfilled in diverse areas of scientific disciplines. For example, the establishment of any underwater facility must investigate aspects of human physiology as well as design the hardware to construct the facility. Thus, this particular demand places a burden of inquiry upon a variety of investigators of research systems.

2. Nature of Scientific Inquiry - The intellectual pursuit of the unknown as manifested in the underwater presents a new domain that remains largely unconquered. Thus, the challenge of scientific research stems, in part, from the desire to increase man's general body of knowledge.

RESEARCH SYSTEMS

Research systems represent the means by which scientific investigation can occur.

1. Institutions - Refers to the formal organizations that initiate and supervise a research project, including all private academic groups, industry, government, etc.

2. Instruments - Include the methods and tools that enable researchers to measure or observe ocean phenomena. This category encompasses the full array of sensing and recording devices employed in the underwater. It also would include any direct human observation of the underwater environment that enhances the basic research process.

3. Human Resources - Represent the actual investigators, the physiological and psychological studies conducted on humans, and the individuals who participate or live in the underwater environment.

PHENOMENA OF THE OCEAN

The phenomena of the ocean represents the generalized areas in which scientific research is directed, and incorporates the major issues that should be addressed for the implementaiton/development of underwater activities.

1. Properties of the Ocean - Includes all the physical, biological, and chemical components which interact to create the underwater environment. This section also includes the properties of the ocean bottom and those below the bottom.

2. Marine Life - Are all the species which reside in the underwater environment, including plants and microorganisms.

3. Engineering Concepts - Includes all the operational components and associated hardware which are required for underwater activities.

4. Management/Policy Issues - Are the array of concepts that can be deployed to operate in the underwater: zones, restricted areas, international agreements, territorial waters, etc.

CHAPTER 12: UNDERWATER/MARINE HABITATION

DEFINITION

For the purposes of this study, underwater/marine habitats are defined and classified as follows:

Habitat	Location
Temporary Commercial Work Stations/Living Quarters	Sea Surface
Temporary Scientific Research Stations/Living Quarters	Subsea Surface
Recreational Habitats	
Permanent Living Quarters/Residential Complexes	

Commercial work stations include underwater habitats or sea surface platforms/structures employed to provide selected technical/engineering/related support personnel with living space, generally on a temporary or rotational basis, to perform certain functions vital to the maintenance, sustainability, and overall operation of man-made marine environment facilities, e.g., welding underwater pipelines, plugging leaks in offshore wells, and drilling for oil and gas in remotely situated fixed pile production platforms.

Scientific research stations/living quarters include habitats such as the U.S. HYDROLAB and the German underwater laboratory HELGOLAND. Facilities such as these provide diver-scientists with a useful base of operations, usually temporary in duration, to observe, monitor, assess certain marine/oceanographic phenomena, e.g. fish stock, endangered species, ocean chemistry, pollutant levels, and marine biology.

Recreational habitats include various facilities in the underwater environment which provide some shelter for persons or stay during their recreation/leisure time. Underwater hotels, restaurants, and observation centers provide examples.

Permanent living residential facilities both on the sea surface and below it are concepts which to date have not been applied. Permanent habitats include envisioned sea cities in the underwater/marine environment designed as long-term dwellings for either small or large residential populations. It must be assumed also that some industrial/commercial support complexes and activities would be vital to continuous day-to-day operation of such centers.

BACKGROUND

As the "underwater world" emerged into prominence, and the related technological capabilities for exploring, using, and enjoying it developed, concepts of human underwater habitats developed concurrently. As noted earlier, these habitats are generally employed to accomplish some form of work. Yet present concepts also foresee habitats employed for recreational purposes, or even for long-term, permanent living. One interesting concept, for example, is that of an underwater prison. Maximum security could be obtained easily due to the problems of depressurization. Such a facility would be virtually "escape proof" with minimal investment in security guards or equipment.

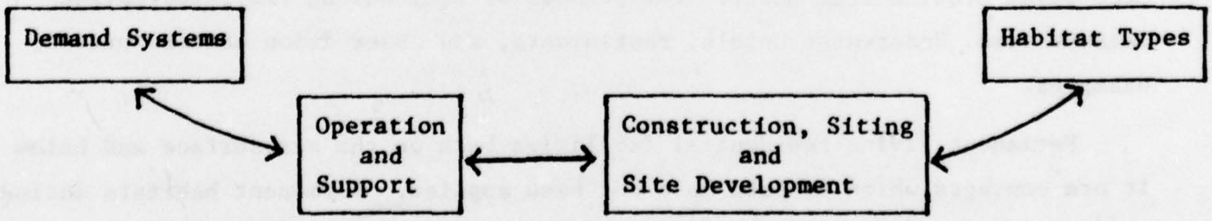
Some visionaries foresee emerging underwater and/or floating communities with up to several thousand inhabitants, complete with the associated infrastructure utility and support systems.

In any event, a novel and new epoch in marine history is opening. This era, in spite of disagreement over its date of fruition, will entail living below the surface or on the surface of the water for various purposes and times in facilities other than military submarines.

FUNCTIONAL SYSTEM

The functional system essentially connects the network of demands which give rise to underwater habitation and the specific types of habitat which could fulfill this demand. These two ends of the system are connected through a network of systems for siting, constructing, and supporting the habitat (see Figure 12-1).

FIGURE 12-1: FUNCTIONAL SYSTEM: HUMAN HABITATS



The demand systems usually emerge from one or more of the following needs/ desires:

- The urgency for underwater work stations to accomplish various commercial endeavors
- The need for underwater stations related to military operations
- The need for underwater stations to undertake scientific work
- The desire for underwater recreational habitats
- The demand for underwater long-term living facilities

Siting systems require determinations of certain characteristics or standards necessary in order to assure habitat facilities are functional within a given area and for the intended purposes. Siting systems also include determination of possible sites for location of the habitat. In some instances, location is determined largely by where the economic activity may occur. In other instances, siting may be highly discretionary, as for example in the case of underwater recreational centers such as restaurants or observation points.

The basic structural components for underwater habitats usually are constructed on land. In most cases, the entire habitat may be constructed on land and simply sunk into place. Some form of mooring generally is required unless the habitat is designed to remain suspended or retain full mobility.

Operations and support systems entail procedures, devices, and instruments to assure the habitat serves its purpose effectively while providing life support to the persons inside. These systems may range from complex instrumentation and repair capabilities, to oxygen control and waste recycling or disposition, to pressure control. Appropriate means of ingress and egress also are important features of each system.

GEOPHYSICAL PERSPECTIVES

Underwater habitation conceivably can take place anywhere in the marine environment. Nonetheless, there presently are depth limitations for living underwater. Most scientific research and commercial work habitats operate at depths of 25 feet to 100 feet, although there are habitats capable of operating at 550 feet.

Sea surface habitation, based on present technology and engineering concepts, has been estimated to be most feasible in shoal waters between 25-50 feet. Sea areas designated as shallow are believed to cover about 10% of the total ocean environment. Feasibility studies have concluded that areas most suitable for the

siting of a sea city include: Martha's Vineyard off North America, the Gulf of Mexico, stretches of the Yellow Sea and the East China Sea, the Baltic Sea, the North Sea, the Irish Sea, and other relatively shallow bodies of water.

TAILORED FORECAST

BASIC CONCEPTS

The basic concepts associated with underwater human habitat activity are outlined below and in Figure 12-1. The tailored vignette and associated forecasts conclude the chapter.

Demand Systems

An array of national needs and demand systems actuate the development and application of human habitats in the underwater environment, including:

- Need for military operations, bases, installations to be placed in key defensive positions
- The need by commercial industry to provide at least temporary living quarters for key personnel working for great lengths of time in this environment
- The demand for habitats by scientists to further explore the underwater environment, frequently requiring lengthy stays to collect and analyze data
- Evolving demand for recreational habitats to view or participate in the aesthetic pleasures of the underwater environment
- Increasing demand for alternative living space as available land sitings fail to meet the need of rapidly growing populations

Functional Systems

Based on the above demands, habitats are constructed and employed to serve one or more functions, including:

- Military base or installation
- Commercial work stations
- Scientific research labs
- Recreational habitats, e.g. hotels, restaurants, etc.
- Residential complexes, both underwater and those which float on the sea surface

Siting Systems

At present, most underwater habitats can best operate in relatively shallow waters. Floating sea cities also require shallow water based on current engineering and construction capabilities. Temporary siting of underwater habitats for commercial or scientific purposes is contingent on the locational need for such activitiy. For instance, if an underwater pipeline needs extensive welding, the habitat will be missioned in that area; if a selected fish stock requires observation and monitoring due to a threat imposed upon this species, a scientific research habitat will be dispatched to go to the depths where these fish dwell.

In sum, siting systems are usually determined by where the need exists in the underwater environment. There are possible exceptions to this rule, e.g., an alternative sea surface or underwater siting for a residential complex could take place wherever desired given suitable geophysical and environmental phenomena.

Construction Systems

Underwater habitats, whether used for temporary commercial, or scientific purposes, or for permanent living below or on the surface of the sea, usually are built in land-based facilities. Thereafter, the habitat is transported to a chosen marine site to serve a predetermined purpose/function. The land-based construction system is a crucial determinant to the availability of underwater or sea surface habitation structures and complexes. The degree to which certain materials are available, the relative availability of a work force capable of designing and constructing these structures, the capacity of production processes, and the extent of national priorization for building these structures rather than gearing economic activity towards other objectives, will all be actively driving or inhibiting construction of habitats or the prefabricated material necessary for erecting a floating sea city.

Operations/Support

Underwater and sea surface habitat structures require a host of support systems essential for sustaining the life residing within the structure/installation. We can briefly categorize the types of habitats and the related support systems which these entail as follows:

Temporary underwater habitats

- Short-term life support systems
- Ingress/egress systems
- Selected functional instruments and instrumentation
- Communication networks
- Sea surface support craft
- Support divers

Temporary sea surface habitats

- Suitable living quarters
- Selected functional instruments and instrumentation
- Communications networks
- Other accomodations essential for well-being on a short-term basis

Permanent undersea habitats

- Long-term life support systems
- Ingress/egress systems
- Selected functional instrumentation
- Communication networks
- Self-sufficient complementary resources
  - Sub-sea desalination plant
  - Self-supporting energy system
  - Underwater waste disposal system
- Some economic activity to make such an undersea residential complex viable over long run

Permanent sea surface habitats

- Floating or fixed pile platforms
- Pontoons
- Breakwater walls
- Host of support craft
- Communication networks
- Self-sufficient complementary resources (water, energy, waste disposal system, etc.)
- Some economic activity to make sea surface complex viable over long-run

Key Driving Forces, Key Barriers, and Obviating Factors

Figure 12-1 outlines the driving forces, barriers, and obviating factors associated with our forecast of underwater or sea surface habitation. The tailored vignette discusses in greater detail some of the more salient points from this figure.

FIGURE 12-1: TAILORED FORECAST FRAMEWORK: HUMAN HABITATS

BASIC TECHNOLOGICAL CONCEPTS	KEY DRIVING FORCES	KEY BARRIERS	OBVIATING FACTORS
<u>Demand Systems</u> Military Operations Commercial activities Scientific Recreational Living space <u>Habitat Types</u> Military bases/ installations Commercial work-stations Scientific research labs Recreational habitats e.g. hotels Residential complexes <u>Siting Systems</u> Site determination Habitat Specifications <u>Construction</u> Shore-based Placement Type/features <u>Operation/Support</u> Life support system Functional instruments Ingress/egress systems Communications Sea surface support craft Self-sustaining resources and economic activity Logistics	Emerging needs associated with the military and economic activities Growing prominance of marine environment in terms of scientific investigation Emerging prominance of underwater environment in terms of recreational and leisure time potentials Increasing interests in conservation/ aesthetics and desire to "observe" on part of public Evolving institutionalization in "promotion" of underwater environment Emerging technological capability Frontier mentality	Remaining technological barriers Lack of institutional development Psychological barriers Comparative economic costs	Reversal of trend and collapse in emerging offshore economy Ultimate economic or technological non-feasibility

THE TAILORED VIGNETTE

The overall climate for the construction and widespread application of temporary underwater habitats will be favorable. Operations and communities from many different national sectors will be at the forefront of the rapid development and advanced improvement in these habitats. We can expect significant promotion of this concept by the:

- Military - The need to better camouflage and seclude key military installations will intensify as the century comes to an end. It is difficult to pinpoint whether underwater bases will be located within U.S. territorial borders, or at what depths. It does seem certain at this time, however, that bases will be built in the land-based environment, and later brought out to sea and submerged. We also expect that these installations will be mobile, perhaps not extensively, but independently motorized to the point where they can be easily transferred to another location should determination of their position be made by foreign intelligence.

- Commercial - The scope of offshore mineral extraction will expand widely during the forecast period. Further, the employment of comprehensive sub-sea pipeline networks is foreseen. These accelerating commercial activities will require persistent maintainance; much of this maintenance will be of underwater nature. Private sector R&D in the field of underwater habitats will aim its effort primarily at increasing the depth capability of these structures, as well as the length of time work habitats can remain at these depths. Commercial underwater work stations/ habitats will be designed similar to the military habitats discussed above, with some exceptions, e.g., the mobility of these commercial stations will not be as great.

- Scientific - The level of underwater scientific analysis and research during the forecast period will broaden considerably. Although underwater habitats will be used, specially designed, highly sophisticated scientific submersibles will find greater application. Submersibles will be equipped with accomodations for relatively long stays in this environment; the greater mobility of submersibles will permit scientists to follow completely investigation of reefs which might extend for many miles, or pursue schools of fish under scrutiny.

- Recreational - Technological breakthroughs, declining economics as front-end costs are expended in the above activities, and the likely spillover subsequent to the development and application of the concepts discussed above will find use in the recreational sector. Nonetheless, actual employment of the concepts will not be developed until late in the forecast period.

Increasing population and accelerating industrialization in the U.S. is likely to continue to place a number of restraints on the land environment. In order to accomodate the above trends, future housing construction will concentrate on high density dwellings; air pollution will be closely monitored, and laws and regulations will increase in number and composition requiring the installation of a host of devices to lessen the amount of pollutant particles escaping into the air. A number of projects will be undertaken on land-water fringes to extend commercial or residential areas. Many of the nation's harbors, for example, will need to expand outward into the water in order to meet the demands made by rapidly escalating shipping volumes. *Late in the forecast period, we expect a number of feasibility studies to be sponsored and implemented by the sector to determine potential alternative offshore, underwater habitation sites. It is conceivable that a small-scale experimental community will be constructed and operating before the turn of the century. Even given this, however, we do not foresee this facility constructed underwater. On the contrary, it is likely to be a floating or fixed pile site. We do not expect to see the construction of a large-scale sea city above or below the sea surface during the forecast period.*

The operational features and characteristics of temporary habitats for military, commercial, scientific, and recreational purposes will vary considerably, and consist of the following:

- <u>Military</u> - Due to the sensitive nature of military operations, it is difficult to cite here what kinds of devices and capabilities military installations underwater will have. We suspect these bases would offer a host of surveillance and monitoring equipment, house a fairly large number of personnel, and perhaps even employ a network of defensive and offensive weaponry. Furthermore, it seems likely that these structures will need to be highly mobile in order to relocate given determinations of position by foreign intelligence.

- <u>Commercial</u> - Most temporary commercial underwater habitats will be located in high-density offshore mineral extraction activity areas. Specialized subsea work stations will house 3 to 10 workers. For long-term assignments, these workers will be assigned on a rotational basis. The station itself

will be highly mobile. Surface-based working quarters on offshore platforms will be used extensively. The range of accomodations offered on these structures will broaden significantly in order to induce a larger volume of workers to take assignments on these relatively remote, isolated platforms.

- <u>Scientific</u> - Although subsea habitats employed for scientific purposes will have many features similar to their commercial counterparts, there will be distinctions. This type of habitat generally will be capable of descending to much greater depths. Accomodations will not be as extensive for the scientists volunteering to go to below the sea surface to investigate certain phenomena. The variety of instrumentation on these structures will be more diverse than that found on commercial habitats.

- <u>Recreational</u> - Construction of underwater recreational facilities most likely will occur later in the forecast period as front end costs for this relatively new technology are expended in other economic sectors. Floating hotels with some rooms underwater seem possible. Subsea restaurants with ample observation points might be attached. The depth of these recreational sites is not likely to be much deeper than 25 to 50 ft. Accomodations at each site would be for less than one-hundred persons. Overall, the total number of sites such as these is not likely to exceed a dozen within U.S. territorial waters.

It does appear possible that other purposes might be served through the construction and utilization of underwater habitats. One such concept would be a maximum security prison. This facility could be a supplemental attachment to an underwater military base/installation. We believe that an experimental facility with this function in mind is likely to be operational in U.S. territorial waters before the turn of the century. Other nations also might seek development and employment of underwater prisons.

FIGURE 12-2: TAILORED VIGNETTE: UNDERWATER/MARINE HABITATION

POTENTIAL DEVELOPMENTS	PROBABILITY/TIMING 1981-85	1986-92	1992-2000
URGENCY FOR THE CONSTRUCTION AND APPLICATION OF UNDERWATER MILITARY HABITATS/INSTALLATIONS EMERGES	G	G	H
NEED FOR TEMPORARY, UNDERWATER COMMERCIAL WORK STATIONS INCREASES	H	H	G
• EMPHASIS PLACED ON WORKING UNDERWATER AT GREATER DEPTHS	H	H	G
• FOR MUCH LONGER PERIODS OF TIME	H	H	G
CONTINUING DEMAND TO UNDERTAKE SCIENTIFIC ANALYSIS AND RESEARCH IN UNDERWATER ENVIRONMENT	H	H	G
DEMAND FOR TEMPORARY RECREATIONAL HABITATS WILL EMERGE	L	F	H
INCREASING LIMITATIONS FOR AVAILABLE LAND LIVING SPACE	G	G	H
• FURTHER CONSTRUCTION OF HIGH DENSITY LIVING ACCOMODATIONS	H	H	H
• NUMBER OF PROJECTS UNDERTAKEN ON LAND-WATER FRINGES TO EXPAND COMMERCIAL AND/OR ACTUAL LIVING SPACE	G	H	H
• IMPLEMENTATION OF FEASIBILITY STUDIES TO DETERMINE ALTERNATIVE HABITATION SITES UNDER AND ON SURFACE OF SEA	L	H	H
PERMANENT UNDERWATER AND SEA SURFACE HABITATION SITES WILL NOT FIND APPLICATION	H	H	G
• ALTHOUGH CONSTRUCTION OF SMALLER SCALE EXPERIMENTATION COMMUNITY IS CONCEIVABLE	M	L	G
• SPURRED BY ADVENTURIST, FRONTIER MENTALITY OF SMALL NUMBER OF PRECIPITATORS/PARTICIPANTS	M	L	G
• GIVEN CONSTRUCTION OF SUCH A SITE, UNLIKELY THAT CITY WILL INCLUDE SELF-SUSTAINING RESOURCES AND ECONOMIC STRUCTURE	H	H	H
TEMPORARY HABITATS FOR COMMERCIAL, SCIENTIFIC, AND RECREATIONAL PURPOSES WILL CONSIST OF:			
• SPECIALIZED SUBSEA COMMERCIAL WORK STATIONS	H	H	H
• • HOUSE MINIMAL NUMBER OF WORKERS	G	G	H
• • ASSIGN PARTICIPANTS ON ROTATIONAL BASIS	H	H	G
• • BE EMPLOYED IN AREAS CHARACTERIZED BY HIGH DENSITY OFFSHORE MINERAL EXTRACTION	H	G	G
• • OFFER GREAT DEGREE OF MOBILITY TO TRAVERSE WITHIN SELECTED EXTRACTION SITE, OR BE TRANSFERABLE TO NEW WORK ASSIGNMENTS IN OTHER AREAS	L	G	H
• SURFACE-BASED WORKING QUARTERS ON OFFSHORE PLATFORMS WILL WITNESS MUCH GREATER APPLICATION	H	H	G
• SUBSEA SCIENTIFIC HABITATS WILL FOLLOW COURSE SIMILAR TO COMMERCIAL COUNTERPART	H	H	G
• • WILL BE CAPABLE OF DESCENDING TO MUCH GREATER DEPTHS	H	H	H

M = minimal G = good
L = low H = high

(Continued)

FIGURE 12-2: TAILORED VIGNETTE: UNDERWATER/MARINE HABITATION (Continued)

POTENTIAL DEVELOPMENTS	PROBABILITY/TIMING 1981-85	1986-92	1992-2000
• WILL NEED TO HAVE MUCH GREATER VARIETY OF INSTRUMENTATION FOR SCIENTIFIC ANALYSIS AND RESEARCH	H	H	H
• RECREATIONAL UNDERWATER STRUCTURES WILL BE CONSTRUCTED AND INCLUDE:	L	G	H
• FLOATING HOTELS WITH SOME ROOMS UNDERWATER	G	G	H
• SUBSEA RESTAURANTS WITH PORTHOLES OR OTHER TYPES OF VIEWING POINTS	L	G	G
CONCEPT OF UTILIZING UNDERWATER ENVIRONMENT AS NATURAL, ESCAPE-PROOF MAXIMUM SECURITY PRISON MAY FIND APPLICATION	M	L	G
• MAY BE SUPPLEMENTAL FEATURE OF UNDERWATER MILITARY BASE	M	G	H
• EXPERIMENTAL FACILITY CONSTRUCTED AND OPERATIONAL IN U.S. TERRITORIAL WATERS	M	L	G
UNDERWATER AND/OR SEA SURFACE RESIDENTIAL COMPLEXES AS PRESENTLY ENVISIONED BY ANALYSTS WILL NOT FIND APPLICATION	H	H	H
• LIKELIHOOD OF SMALL-SCALE EXPERIMENTAL COMMUNITY ON THE SEA SURFACE	M	L	G
• UNLIKELY THAT PERMANENT, LARGE-SCALE HABITATION FACILITY, EVEN EXPERIMENTAL, WILL BE CONSTRUCTED OR DEMONSTRATED	H	H	H
• POSSIBLE THAT FLOATING COMMUNITIES WILL BE EMPLOYED, BUT THESE WILL BE MERELY OLD SHIPS RETROFITTED FOR SUCH PURPOSES	M	L	G

CHAPTER 13: LEGAL AND REGULATORY ACTIVITIES AND SUPPORT SYSTEMS

DEFINITION

Most economic activities are under the purview of state and/or federal authorities. This category represents the complete system of oversight that exists or may exist for the implementaiton of underwater activities. 'Oversight' incorporates the establishment of guidelines, compliance and enforcement with these procedures and judicial processes to correct noncompliance with established regulations.

Excluded from this category are the protection functions, and search and rescue capabilities previously discussed in Chapter 3. However, the myriad of underwater activities that require some form of oversight will have convergent responsibilities that are discussed within this section. The specific areas to be addressed include:

Regulations--the specific requirements which stipulate how an operational facility must exist and establishes the minimum prerequisities necessary for sustained deployment.

Standards--are designated for both equipment specifications and human performance requirements.

Inspection--the onsite observation by humans or the monitoring by any other method to check operational safety and adherence to stated guidelines.

Enforcement--incorporates all methods necessary to protect participants in the marine environment and to guarantee that stipiuated rules are obeyed.

BACKGROUND

Marine regulatory structures and support systems can be traced back throughout our nation's history. The economic emergence of the marine resources has been coupled closely with rules, regulations and enforcement procedures to guide the appropriate functions of all marine activities. Presently a myriad of standards and regulations exist which eminate from diverse agencies and create a quagmire of uncertainty in the critical area of oversight. For example, the agency which sets environmental standards may not be involved in the determination of violators. Also, in some instances, differing agencies have shared responsibility for oversight of a single operational activity, i.e., offshore drilling.

The dynamic and changing aspects of the marine economy will concomitantly affect the support and regulatory structures which guide the specific activities. The overall marine environment will be characterized by these dynamic influences:

- The rapid increase in exploitation of marine resources for energy, mineral, and agricultural needs.
- The expanded role of the underwater military systems and capabilities.
- The protection of marine operations from unanticipated events including the application of antisocial technologies.
- The management of the ocean to enhance its physical or biological properties and to resolve conflicts over its competitive usage.

FUNCTIONAL SYSTEM

The functional system as depicted in Figure 13-1 consists of three major components: the underwater activities which are subject to some form of regulation or support, the system which initates these requirements and insures their compliance, and the actual achievement of the objectives of regulation and support. The specific elements of the functional system are discussed below.

FIGURE 13-1: FUNCTIONAL SYSTEM

LEGAL & REGULATORY ACTION	REGULATORY & SUPPORT SYSTEMS	ACHIEVEMENT OF OBLIGATIONS
Underwater Activities	Legislation/Guidelines	Safety in Underwater
Indirect Regulatory Action	Specific Regulations/Promulgations	Protection in Underwater
	Compliance Requirements	
	Compliance Safeguards	

Legal and Regulatory Actions

1. Underwater activities - The operation of underwater activities requires that each facility or operator conforms to established procedures and regulations.

2. Indirect regulatory action - Specific legal requirements that impact upon operations in the marine environment, may originate in documentation that was designed for other purposes. For example, a federal stipulation about the minimum work area for a scientific laboratory may be applied for underwater research submersibles.

Regulatory and Support Systems

1. Legislation/Guidelines - The broad federal or state statutes that are enacted to guide or shape industrial behavior, environmental quality or operational safety consist of the type of initiatives representative of this category. The documentation may or may not be designed specifically for underwater activities; the significant aspect, however, is that the ultimate regulatory process applied originates at this point.

2. Specific Regulations/Promulgations - The broad guidelines established previously take more specific and concrete form by agency or regulatory authority reformulation. Thus, operational requirements are developed for and specific standards set for equipment, space, emissions, personal capabilities, etc.

3. Compliance Requirements - The fulfillment of the specific requirements often demands changes in personnel or equipment. Any appropriate action that is undertaken so that an operation meets the enacted guidelines is included in this category.

4. Compliance Safeguards - The intervention by authorities, most likely of a regulatory perspective, to insure operational safety and overall compliance form the crux of this area. The major methods to insure compliance or to preempt noncompliance are inspection and enforcement.

BASIC CONCEPTS

The basic concepts upon which this forecast were derived are outlined in Figure 13-1. Basic concepts deliniate the various means by which regulatory or legal requirements can be achieved successfully.

Preventive Methods

The most desirable method to insure safety in the underwater and operational compliance with established regulations is by a series of preventive procedures. Concepts that relate to prevention include:

Preventive Methods--Individual or Isolated Operations

- Equipment standards--the specific requirements designed to insure operational safety, protect the marine environment or prevent abuse to resource exploitation. The equipment standards fulfill the objectives implicitly stated in regulatory guidelines or laws.
- Personnel standards--those sanctions made upon individuals to insure that underwater operators fulfill certain skill and knowledge requirements and in some cases behavioral standards.
- Operational standards--those parameters in which an underwater facility must conform. Standards to be set as to locale, size, emissions etc.

Preventive Methods--Interactive Activities

- Navigational systems and aids including electronics, visual, radio or sonic, radar controlled, buoys, satellite tracking stations, and various other forms of detection systems.
- Movement controls including shipping lanes, designations, off-limit areas, restricted usage within selected areas or under controlled conditions.
- Zonal controls, the designation of specific areas for activities or nonactivities, and the prohibition of certain activities from certain locales.

Concepts for Inspection and Enforcement

The preceding sections have either implicitly or explicitly enunciated the technological concepts which potentially could be applied to inspection and enforcement systems. The technical requirements for inspection and enforcement can be drawn from those stated particularly in the military, and surveillance and monitoring sections. Similarly, the various modes in which these systems can be deployed are directly analogous to those used in protection of property and life. Specifically, these include all preventive, proactive, and reactive/restoration measures.

TAILORED VIGNETTE

The demand for more effective inspection and enforcement systems will accelerate rapidly, and in direct relationship to the intensity of underwater activities. The emergence of diverse underwater activities has been forecasted throughout Volume II of this report. To insure operational safety each activity will require measures that range from preventive to reactive. In addition, the burden placed upon enforcement systems will be significantly magnified from present systems. (The reader is advised at this point to review the Tailored Vignette, in Chapter 3, on Protection of Property and Life for some of the salient or related issues.) Some of those forecasts which converge with those of this section are restated below.

The range and potential threat from accidents will grow in all categories as a direct result of increased activities. Major drives will be made to instill new regulatory controls to assure that accident prevention programs are designed and executed effectively. These programs will include improved employment of sea zoning, navigational aids, and operational standards for equipment and personnel. This forecast emerges from the fact that potential for accidents rises as the number of actors and types of activities increase and as their density and interrelationship become more complex.

As the array of new legislation is designed and implemented for the expolitation of marine resources, and overall usages in the marine environment, specific inspection requirements will accelerate. The physical inspection of an operational facility, including vessels, will be warranted to insure compliance with legal guidelines. In some circumstances, inspection requirements which heretofore have been exclusively above the water, such as oil rigs, will have an underwater inspection counterpart. Therefore, this forecast obviously is predicated on expanded usage of submersibles and divers, a suggestion that previously has been articulated in other chapters.

The involvement between standard setters (regulatory agencies), compliance modulators, and enforcement agencies will grow increasingly complex and, in some circumstances, act to inhibit the emergence of activities. As stated throughout the forecasts, certain lag periods will develop in the marine environment between the need for certain technologies, law, or operational skills, and their actual implementation. The most apparent type of situation is the 'protection/threat gap.' In the whole regulatory milieux, inevitable lags will emerge between the

advent of new activities and the guidelines needed to insure operational safety. This situation will be compounded by the bureaucratic competition and indecisiveness over who regulates what in the marine environment.

The conflict between private industry and government agencies over the regulation of the marine environment ultimately will be resolved by the creation of a single lead agency to coordinate marine affairs. This agency will act to monitor the marine environment by integrating navigation systems for surface and subsurface vessels with other surveillance systems. In addition, this lead agency will develop an entire new network of equipment specifications related to standards for regulation and enforcement of safety for all underwater operations.

CHAPTER 14: SURVEILLANCE/MONITORING

DEFINITION

Surveillance is the process of receiving signs or signals from a geographical area which provides indication that some form of activity or physical presence exists in that locale; monitoring a component of surveillance involves maintaining a "track" on elements or objects in a specified area after the presence has been indicated. From the perspective of this study, surveillance requirements cross most major chapter headings.

The two basic components of the surveillance process are the initial data/information collection stage in which a series of questions about the characteristics of movement are addressed, and an interpretive stage which analyzes the input data and derives a judgment as to the type and level of activity. For the specific purposes of this study, the term surveillance includes surveillance of the subsurface marine environment, surveillance of the surface and above-surface marine environment for signs relating to the subsurface marine environment, and surveillance from the subsurface marine environment.

BACKGROUND

Prior to World War I, the primary purpose of surveillance entailed the visual look-out both for ships and other objects, and for signs of weather change. The advent of the aircraft improved the capacity to achieve this objective successfully. The introduction of the submarine for military purposes made new demands of surveillance in the marine environment; an acoustic capability for the underwater monitoring was needed for security purposes.

During World War II, advances in cryptographic technology and radar were developed. Surveillance concepts became increasingly concerned with electromagnetic radiation both as a method and, in some circumstances, as an object of surveillance.

Presently, surveillance provides inputs to the intelligence function of the nation, and constitutes an important element of the ICBM defense. Technological advances in satellite photography, data and signal processing, and the interpretive capability of magnetic signatures have all enhanced the overall surveillance capability.

The future surveillance requirements will be established in a dynamic and changing environment. The events that will determine the shape and orientation of these surveillance systems include the following areas:

- Antisocial technologies: the aforementioned problems of a threat/protection gap (see Chapter 3)
- Military preparedness: the increasing shift to an underwater operational capacity
- Resource exploitation: the extraction of minerals and development of offshore energy systems
- Policy issues: international treaties, territorial rights, sea zones, etc.

The functional system consists of the basic components outlined in Figure 5-1.

FIGURE 5-1: THE FUNCTIONAL SYSTEM

Surveillance Systems/Demand	Means of Surveillance	Object of Surveillance
Threat Identification	Transmission System	Vessels/Platforms/Buoys
Intelligence	Visual	Ocean Injections
Navigation	Electromagnetic	Debris
Law Enforcement	Acoustic	Pollutants
Search/Rescue/Salvage		Ocean Marine Species

Surveillance Systems and Demands reflect the motivation factor by which surveillance is initiated and conducted. The type of system ultimately utilized is a function of the requirements of implementation.

Means of Surveillance consist of the array of separate technological alternatives that allow different types of surveillance to be operated.

Objects of Surveillance include all objects, elements, or regions that are specifically chosen as key barometers or indicators that provide the means for interpretive analysis or, in some manner, fulfill the goals of the surveillance system.

GEOPHYSICAL PERSPECTIVE

The entire subsurface region of the marine environment is the object of surveillance. The region is banded by the sea surface, the sea/ocean bottom, and the shore. In the region adjacent to each continental boundary is the continental shelf. Between the shelf and the deep ocean areas are the continental slopes and the continental rises which connect the shelf with the remainder of the region. The water depth over the shelves is generally uniform at several hundred feet as is the water depth over the deep ocean bottoms, about 12,000 feet. The region in and over the shelves contains virtually all of the region's known living and nonliving resources; the nonliving resources that exist beneath the deep sea bed may be extensive but have not yet been thoroughly explored. The one resource known to be present in the deep ocean areas is an abundance of manganese nodules lying on the sea floor. Exploration to date leads to the belief that the energy and mineral resources beneath the surface of the shelf are vast.

From the point of view of surveillance, the region has one dominant characteristic--it is highly impenetrable to all known forms of surveillance mechanism. No known form of electromagnetic radiation penetrates successfully; even high energy cosmic radiation attenuates extremely rapidly upon entering sea water. Magnetic fields penetrate sea water, but only for short distances, and to date no way has been found to modulate a magnetic field for information transmission purposes. Sea water does transmit mechanical vibrations for long distances, especially low frequency vibrations. And this mechanism is the only one to date that has found utility as a surveillance mechanism--in the form of acoustic transmissions. But even acoustic transmissions have a severe limitation; sound rays and beams are refracted by gradients in sea water temperature, density and salinity, different acoustic frequencies are refracted differently. This means that the direction of a sound source or sound reflecting surface is not ascertainable simply by measuring the direction from which the sound base comes. It also means that shadow zones and blind areas exist in the underwater region in which sound from some locations cannot be detected at all; it means that sound channels exist in the region through which sound from auspiciously located sources may travel extremely long distances, e.g., several thousand miles.

The behavior of sound is fairly well understood in terms of its refraction in temperature, density and salinity gradients. Therefore, it is theoretically possible to calculate changes in the direction of a sound beam if sea water temperature and salinity is completely known as a function of position in the

region. Today's state-of-the-art in gathering this kind of information about vast regions of the oceans, and in making real time calculations of sufficient comprehensiveness to be useful, is still in its infancy.

Use of acoustic mechanisms in surveillance or command and control functions is further complicated by the existence of a variety of ambient sound sources in the underwater region; fish and mammal sounds, wind and wave motion on the surface, and ice on the surface, are some of the principal sources. The irregularities in the underwater region boundaries, i.e., the surface, the shore and shelf regions, and the sea bottom, also contribute to scattering and reverberation of the sound, and therefore to complexity in calculating sound paths. As the activity in the underwater region increases, so will the ambient sound noise level increase, thus further complicating the calculation.

Nature's coupling mechanism for transmitting acoustic vibtations from the sea to the air above it, or vice versa, is extremely poor. Thus, at least in today's state-of-the-art, there exists no effective direct way to "listen" for subsurface acoustic signals from positions above the surface.

Indication of gravity and magnetic anomalies have been found in the subsurface region of the marine environment. These anomalies do not adversely affect today's surveillance and monitoring techniques; however, they may be relevant to some to-be-discovered mechanism of surveillance.

BASIC CONCEPTS

Demand Systems

The condition upon which an underwater surveillance system is developed reflects a direct functional relationship to the level and degree of underwater activities. The major component of this demand system includes the following topics.

Threat Identification. The responsibility of national security embodies preventive measures to threats from conventional military organizations and from the development of antisocial technologies. In both of these situations, the underwater environment acts as a shield which often encumbers present technological systems from delineating the specific nature or activity that occurs in the subsurface.

Intelligence. The intelligence function of government incorporates the concept that it is essential for the national interest to maintain an overall awareness of nations or groups' actions and plans. This perspective has operational reality in the underwater environment and is manifested specifically by a surveillance system.

Intelligence systems utilize all mechanisms or techniques that expand the interested party's or sovereign state's knowledge about the unknown. Thus, in the underwater, the intelligence function is served by electronic observation, satellite detection, etc.

Navigation. Navigational requirements within the underwater are predicated upon increased movement of vessels and expanded development of activities such as mining. Navigational aids within the subsurface may include a marking system, communication linkages and zonal controls.

Law Enforcement. The expanding development of underwater and marine activities, the threat of antisocial technologies, and the protection of marine resources increase the associated law enforcement requirements of the marine environment. Specific responsibilities include protection of fishery zones from foreign intrusion, rights of passage, and territorial restrictions.

Surveillance Mechanisms

The operational aspects of surveillance follow a common pattern irrespective of the technology employed or target designated. When viewed in isolation the components of a surveillance system include the geophysical base, transmission device, transmission mode, reception display devices, and the target. The technological concepts that will be key determinants to future surveillance systems are discussed briefly below.

Geophysical Surveillance Base. Miniaturization and microminiaturization are permitting placement of high-power transmitters and receivers on smaller platforms and in more inaccessible locations. Surveillance bases can be located anywhere from satellite to underseas, on large or small platforms, on moving or stationary platforms.

Transmission Devices. The range of active surveillance devices can be extended by technological advances which allow for increasing the amounts of power with efficiency, although the incremental gain per unit power radiated is small. Radiation technology is leading to the capability to propagate energy in highly useful wave, beam and ray forms - e.g. lasers and other coherent radiation forms. Advanced modulation technology is enabling cryptologists to cryptographers to encode transmissions with increasing simplicity and also with increasing security.

Transmission Media. Research will continue to find an electromagnetic "window" in sea water in order to make it more transparent, but this research is not

likely to produce significant progress before the end of the century.

Atmospheric research will produce progress in making use of the characteristics of the atmosphere to reflect, refract, and transmit electromagnetic energy with reliability. This will promote developments in over-the-horizon radar and in meteorology.

Reception/Display Devices

Progress in signal analysis techniques will greatly improve the ability to interpret received signals correctly and to extract maximum information from them.

Advances in data processing will permit the display of a vast array of information about the zones under surveillance and thereby present a panoramic view of relevant situations to decision makers. Data processing progress will also permit display of the same information at many remote terminals simultaneously.

Signal analysis technology is progressing toward the ability to interpret incoming wave forms more accurately and to extract from incoming signals the maximum information. This includes the ability to discriminate among signals from different sources and reflecting media.

Signal processing technology is permitting more ease in reading through natural interference and less sophisticated man-made interference. Deliberate countermeasure techniques also permit the blocking of signals or the injection of false information into signals.

Improvements in signal analysis will likely lead to the ability to detect ocean surface characteristics, chemical, physical, or acoustic, for example, which correlate with the specific underwater activity that it is desired to detect. Advances in data processing technology will also promote increasing ability to handle masses of data in extremely short times, thus further promoting the trend, already begun, toward instantaneous game analysis of current situations - analysis in which the observing decision-maker postulates a tactical course of action, plugs it into his display system, and receives an estimate of his postulated action's effect.

Display devices will be developed which permit individuals in a tactical or operating circumstance to have access to imagery of an entire panorama, for example, on the back of a pulled-down eyeshade.

Targets

Research to make objects accoustically invisible underwater will continue, but with only limited effectiveness to the end of the century.

On the other hand, research to make objects accoustically <u>more</u> visible

underwater will be somewhat more successful. This will lead to the ability to render subsurface submersible and diving operations more safe and secure, and to enhance underwater navigation. The form of this development will be both in coating material and in beacon-like devices.

Associated research will lead to the ability to detect from a vehicle the acoustic reflection characteristics of another type vehicle, and the accoustic radiation signature of another type vehicle.

Analysis will reveal that subsurface structures radiate a characteristic spectrum because of current flows around them which is detectable and identifiable.

The depth to which underwater vehicles can dive and the speed at which they can proceed will increase and the size needed to perform a particular task will decrease with research.

Comparable research with respect to vehicles in the atmosphere and to other phenomena in the atmosphere will be toward making their visibility to electromagnetic surveillance measures controllable - by making them either more or less visible, and by concealing their nature and by emitting or reflecting signals which indicate them to be what they are not.

TAILORED VIGNETTE

The basic national surveillance requirements of the underwater should accelerate rapidly throughout the forecast period. The major environmental factors, including major political developments, which would be necessary to preclude this event from occuring, does not appear imminent. As discussed previously in the chapters on underwater activities, we forecast specific situations or events that seem likely to catalyze the need for an underwater surveillance system. The highlights of future macro/marine factors would include:

- The expanded reliance on the underwater for military systems.
- The development and deployment of antisocial technology by nonmilitary organizations.
- Expanded resource development in minerals, energy systems and agricultural products.
- Adoption of positive management concepts for injection of materials.
- New and accelerated development of underwater vessels and offshore ports.

The above statements capture in part the notion that the whole marine environment will be subject to new and diverse activities which require some form of monitoring to secure safety and prevent violations.

The natural shield that the sea provides from present surveillance systems will not completely be overcome by technological advances. However, some capabilities will improve and allow for more accurate tracking and detection systems. The sea water's resistance to penetration by any known form of surveillance mechanism will not be changed. The stability of the water's resistance is derived from several aspects. First, the entire spectrum of electromagnetic radiation, from cosmic radiation at the high end to infrared and heat at the low end, is attenuated extremely rapidly in the sea. No wave form has been found which offers promises in this regard for more than a very short distance. This condition should remain through the end of the century. Second, acoustic vibrations are readily transmitted through sea water for great distances. As a result, sonic listening devices are able to detect acoustic sources sometimes thousands of miles distant. Convergence zones and sound channels are sometimes formed by various combinations of water temperature gradients which cause sound refraction, and present devices make use of this phenomenon. However, high frequency sound, which is most susceptible to being formed into directional beams, attenuates far more rapidly than low frequency sound. Sound

"beams" of all frequencies are susceptible to refraction by temperature gradients and to distortion by currents which render the location process highly inaccurate. These limitations are being attrited by "brute force" methods of technology, namely, putting more power into the water and placing sonar transmitters at depths more suitable to the gradients. These methods are incrementally effective and progress may be expected, but this progress should be expensive in terms of incremental gain per unit resource input, and will not realize any quantum jump in capability before the end of the century.

The successful application of an underwater surveillance system may require a full integration between military and nonmilitary sponsors, and a technical integration between surface and air surveillance systems. The impenetrability of the ocean to surveillance mechanisms is leading to the use of a second-best alternative, surveillance above the surface, to indicate activities of interest below the surface. This above-the-surface capability should increase at a rate commensurate with the growth of the marine economy and should adopt creations from laser and satellite technology. The expansion of activities in the marine environment will significantly increase the cost of operating a surveillance system. For reasons of economic efficiency, an integrated system among divergent users may be implemented. This does not suggest that the intelligence function or military capability aspect of surveillance will be deferred or transferred to civilian control.

UNDERWATER OPERATIONAL SYSTEM

General Systems and Operations

1) Submersibles

   a. Design Characteristics

      - Manned and unmanned
      - Tethered, untethered, towed
      - Bottom crawlers
      - Remotely controlled
      - Lock in/lock out system
      - Depth range
      - Size variation

2) Habitats

   a. Design Characteristics

      - Temporary underwater
      - Temporary sea surface
      - Permanent underwater
      - Permanent sea surface
      - Lock in/lock out systems
      - Ocean bottom
      - Size variations

3) Working Platforms/Rigs

   a. Design Characteristics

      - Stilt supported
      - Submerged drilling barge
      - Jack-up barges
      - Semisubmersibles
      - Floating platforms
      - Ocean bottom

4) Dredges

   a. Design Characteristics

      - Semisubmersible
      - Submersible
      - Ocean bottom
      - Surface

   b. Functional Type

      - Cutter suction
      - Suction hopper

- Continuous bucket line
- Vacuum cleaner

5. Harvesting Systems
   a. Nets
      - Purse seines
      - Drift nets
      - Bottom dwelling
      - Long lines
      - Trawling
   b. Lines
   c. Hooks
   d. Traps
   e. Electronic stunners
6. Surface Vessels
   a. Size variations
   b. Conventional hull design
   c. Platoon structure
   d. Hydrofoil
   e. Open stern trawlers
7. Divers
   a. Pressurized suits
   b. Tank equipped
   c. Other
      - Dry suits
      - Wet suits
      - Scuba
8. Instrumentation Systems
   a. Navigational aids
      - Transponders
      - Transceivers
      - Cameras
      - Strobes
      - Viewing ports
   b. Communication and surveillance mechanisms
      - Visual

        Direct

        Photography

(Continued)

- Electromagnetic
  - Radar
  - Infrared
  - Laser
  - Other

c. Communication and surveillance components
- Hydrophones
- Cameras
- Underwater transmitters

9. Underwater Hardware

a. Manipulators

b. Cables
- Support
- Electric

c. Pipelines

d. Buoys

e. Mines

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